



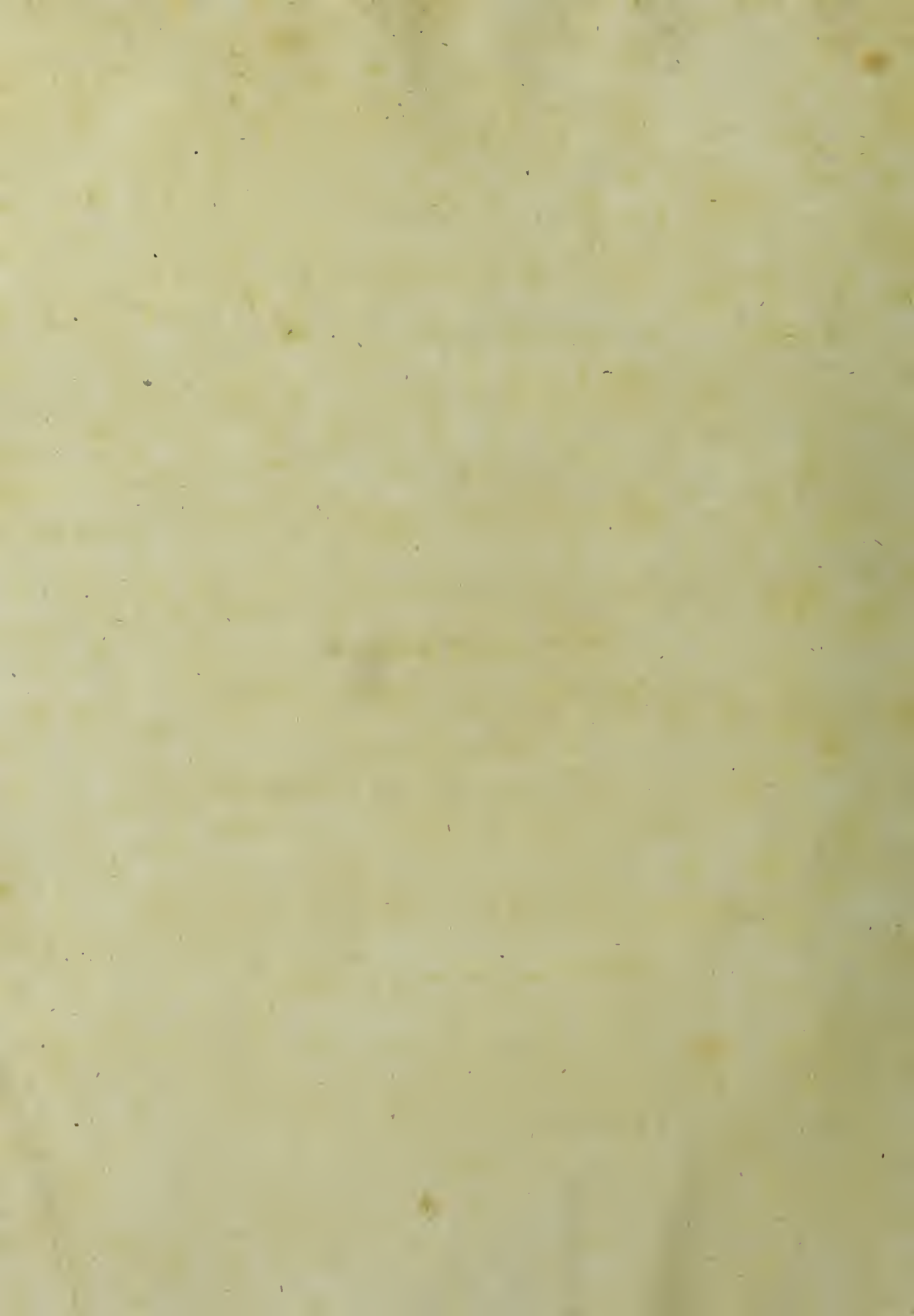
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The Marquis of Stafford.





PHYTOLOGIA;

OR THE

PHILOSOPHY

OF

AGRICULTURE

AND

GARDENING.

WITH THE THEORY OF DRAINING MORASSES,

AND WITH AN

IMPROVED CONSTRUCTION OF THE DRILL PLOUGH.

By ERASMUS DARWIN, M.D. F.R.S.

AUTHOR OF ZOONOMIA, AND OF THE BOTANIC GARDEN.

Suadent hæc CREATORIS leges a simplicibus ad composita. LIN. ORD. NAT.

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DEDICATION.

TO SIR JOHN SINCLAIR, Baronet, to whose unre-mitted exertions, when President of the Board of Agriculture, many important improvements in the cultivation of the earth were accomplished and recorded; this Work, which was begun by the instigation of his letters to the author, is dedicated with great respect.

Derby, Jan. 1, 1799,

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INTRODUCTION.

AGRICULTURE and GARDENING, though of such great utility in producing the nutriment of mankind, continue to be only Arts, consisting of numerous detached facts and vague opinions, without a true theory to connect them, or to appreciate their analogy; at a time when many parts of knowledge of much inferior consequence have been nicely arranged, and digested into Sciences.

Our imperfect acquaintance with the physiology and economy of vegetation is the principal cause of the great immaturity of our knowledge of Agriculture, and Gardening. I shall therefore first attempt a theory of vegetation, deduced principally from the experiments of Hales, Grew, Malpighi, Bonnet, Du Hamel, Buffon, Spallanzani, Priestley, and the Philosophers of the Linnæan School, with a few observations and opinions of my own; some of which have in part already appeared in *Zoonomia*, and in the notes to the *Botanic Garden*, but are here corrected and enlarged. To the former of which works I hope this may be esteemed a supplement, as it is properly a continuation of the subject.

My inducement to commence this work, after it was suggested to me by the letters of Sir John Sinclair, was a belief, that the experiments and observations already made on the growth of plants, with the modern improvements in chemistry, were sufficiently numerous and accurate for the establishment of a true theory of vegetation; so much wanted to connect the various facts in the memory, to appreciate their value, and to compare them with each other; and finally to direct the prosecution of future experiments to useful purposes.

PHYTOLOGIA.

PART THE FIRST.

PHYSIOLOGY OF VEGETATION.

SECT. I.

THE INDIVIDUALITY OF THE BUDS OF VEGETABLES.

1. *Vegetables are inferior animals. A bud torn from a tree will grow; vines and hawthorns so planted. Many kinds of fruit ingrafted on one tree.* 2. *The bark and branches of hollow trees remain alive. Caudex of herbaceous plants. Caudex of buds.* 3. *Which descending, form a new bark over the old one. These bark vessels occasionally inosculate. Upper lip of wounds of the bark grows downwards.* 4. *Flower-buds are individual beings; do not so certainly grow by inoculation as leaf-buds; are biennial plants like leaf-buds, but die in autumn without enlarging the size of the tree by their progeny.* 5. *In what vegetables differ from animals; they have not muscles of locomotion; nor organs of digestion.* 6. *In what they resemble animals. They have absorbent, umbilical, placental, and pulmonary vessels, arteries, glands, organs of reproduction, with muscles, nerves, and brain.* 7. *Progress of a young bud, and of a seed. The plumula, radicle, and caudex of a bud.* 8. *Buds and seeds are biennial beings. How they differ. The disunion of the pith distinguishes buds from each other, and thus evinces their individuality.*

I. **W**E have so accustomed ourselves to consider life and irritability to be associated with palpable warmth and visible motion, that we find a renitency in ourselves to ascribe them to the comparatively cold and motionless fibres of plants. But to reason rightly on many vegetable phenomena we shall find it necessary first to shew, that vegetables are in reality an inferior order of animals.

If a bud be torn from the branch of a tree, or cut out and planted

in the earth with a glass cup inverted over it, to prevent the exhalation from being at first greater than its power of absorption; or if it be inserted into the bark of another tree, it will grow, and become a plant in every respect like its parent. This evinces that every bud of a tree is an individual vegetable being; and that a tree therefore is a family or swarm of individual plants, like the polypus, with its young growing out of its sides, or like the branching cells of the coral-insect.

The present most approved method of propagating vines in hot-houses consists in cutting off a single eye of a vine-stalk with about an inch of the stem above the eye, and two or three inches below it; and setting this aslant in the bark-bed with the eye about an inch or less beneath the surface, pointing upwards; and I have seen a quick-set or hawthorn hedge, cretægus, propagated in the same manner by planting twigs in the ground with one bud only above the soil.

Mr. Barns, in a treatise on Propagating Fruit-trees (1759, Baldwin, London) asserts, that he cut a branch into as many pieces, as there were buds or leaves upon it; and wiping the two wounded ends dry, he quickly applied to each a cement previously warmed, which consisted chiefly of pitch, and planted them in the earth with unfailing success. The use of this cement I suspect to consist in its preventing the bud from bleeding to death, though the author ascribes it to its antiseptic quality. And lastly, in the inoculation and ingrafting of fruit-trees, five or six different kinds of pears are frequently seen on the branches of one tree, which could not then properly be termed an individual being.

2. When old oaks, or willows, lose by decay almost all their solid internal wood, it frequently happens, that a part of the shell of the stem continues to flourish with a few healthy branches. Whence it appears, that no part of the tree is alive but the buds, and the bark, and the root-fibres; that the bark is only an intertexture of the caudexes

dexes of the numerous buds, as they pass down to shoot their radicles into the earth; and that the solid timber of a tree ceases to be alive; and is then only of service to support the numerous family of buds in the air above the herbaceous vegetables in their vicinity.

A bud of a tree therefore, like a vegetable arising from a seed, consists of three parts; the plumula or leaf, the radicle or root-fibres, and the part which joins these two together; which is called the caudex by Linneus when applied to intire plants; and may, therefore, be termed caudex gemmæ when applied to buds.

In herbaceous plants the caudex is generally a broad flat circular plate, from which the leaf-stem ascends into the air, and the radicles or root-fibres descend into the earth. Thus the caudex of a plant of wheat lies between the stem and the radicles, at the basis of the lowermost leaf, and occasionally produces new stems and new radicles from its sides. Thus the caudex of the tulip lies beneath the principal bulb, and generates new smaller bulbs in the bosom of each bulb-leaf, besides one principal or central bulb; the caudex of orchis, and of some ranunculuses, lies above their bulbous roots; whereas the caudexes of the buds of trees constitute the longitudinal filaments of the bark, reaching from the plumula or apex of the bud on the branch to the base of it, or its root-fibres beneath the soil.

Nor is this elongation of the caudexes of the buds of trees unanalogous to what happens to some herbaceous plants, as in wheat; when the grain is buried two or three inches beneath the soil, an elongation of the caudex occurs almost up to the surface, where another set of fibrous roots are protruded, and the upright stem commences. The same happens to tulip-roots when planted too deep in the earth, as I have witnessed, and I suppose to those of many other vegetables.

This caudex of the buds of trees not only descends as above described, but also ascends from each bud to that above it; as on the

long shoots of vines, willows, and briars; in this respect resembling the wires of strawberries and other creeping plants. Thus the caudex of perennial herbaceous plants consists of a broad plate, buried beneath the soil to protect it from the frost; while the caudex of buds of trees consists of a long vascular cord extending from the bud on the branch to the radicle beneath the earth, and endures the winter frosts without injury.

3. These buds are properly biennial plants, as they are generated in one summer, and in the next either produce seeds and die, or produce other buds, whose caudexes form a new bark over the former one, that of the last year first becoming a softer or more porous wood, called *alburnum*, or sap-wood, and gradually hardening into solid timber, which ceases to possess vegetable life.

These long caudexes of the individual buds of trees, which constitute their bark, are well seen in the cloth made from the mulberry-bark brought from Otaheite. On inspecting this cloth the long fibres are seen in some places to adhere, where it is probable they occasionally inosculate, like some of the vessels in animal bodies; because when some buds are cut off, the neighbouring ones flourish with greater vigour, being supplied with more of the nutritious juices.

This informs us why the upper lip of an horizontal wound made in the bark of a tree grows downwards with so much greater expedition than the under one grows upwards to meet it; as the descending caudexes of the individual buds are supplied directly with nutriment from the vegetable arteries after the oxygenation of the blood in their leaves; whereas the under lip of the wound is nourished only by the lateral or inosculating vessels, which supplies us with another argument against the individuality of trees, and in favour of that of buds.

4. The buds producing flowers are each an individual being as well

as

as the leaf-buds above described, though they are probably not so easily capable of transplantation into the bark of other trees by inoculation; as, I believe, it is from the mistake of the gardeners in choosing flower-buds instead of leaf-buds to inoculate with, that so many buds die in this mode of propagation. Nor does the existence of many male and female parts in one flower destroy its individuality any more than the number of pups of a sow or bitch, or the number of their cotyledons, each of which during gestation belongs to a separate fetus.

The flower-buds as well as the leaf-buds are properly biennial plants, as they are produced in the summer of one year, and perish in the autumn of the next; but as the new buds generated by leaf-buds continue to adhere to the parent, they are furnished with their numerous caudexes, which form a new bark over the old one, whereas the flower-buds generate seeds, which when mature fall upon the ground, and thus they die in the autumn without increasing the size of the parent-tree by the adhesion of their progeny like the leaf-buds.

5. These buds of plants, which are each an individual vegetable being, in many circumstances resemble individual animals; but as animal bodies are detached from the earth, and move from place to place in search of food, and take that food at considerable intervals of time, and prepare it for their nourishment within their own bodies, after it is taken; it is evident, that they must require many organs and powers, which are not necessary to a stationary bud. As vegetables are immoveably fixed to the soil, from whence they draw their aliment ready prepared, and this uniformly, and not at returning intervals; it follows, that in examining their anatomy we are not to look for muscles of locomotion, as legs and arms; nor for organs to receive and prepare their aliment as a mouth, throat, stomach, and bowels, by which contrivances animals are enabled to live many hours without new supplies of food from without.

6. The parts, which we may expect to find in the anatomy of vegetables,

vegetables, which correspond to those in the animal economy, are first a threefold system of absorbent vessels, one branch of which is designed to imbibe the nutritious moisture of the earth, as the lacteals imbibe the chyle from the stomach and intestines of animals; another to imbibe the water of the atmosphere, opening its mouths on the cuticle of the leaves and branches, like the cutaneous lymphatic vessels of animals; and a third to imbibe the secreted fluids from the internal cavities of the vegetable system, like the cellular lymphatics of animals.

Secondly, in the vegetable fetus, as in seeds or buds, another system of absorbent vessels is to be expected, which may be termed umbilical vessels, as described in Sect. III. of this work, which supply nutriment to the new bud or seed, similar to that of the albumen of the egg, or the liquor amnii of the uterus; and also another system of arterial vessels, which may be termed placental ones, corresponding with those of the animal fetus in the egg or in the womb, which supply the blood of the embryo with due oxygenation before its nativity.

Thirdly, a pulmonary system correspondent to the lungs of aerial animals, or to the gills of aquatic ones, by which the fluid absorbed by the lacteals and lymphatics may be exposed to the influence of the air. This is done by the leaves of plants, or the petals of flowers; those in the air resembling lungs, and those in the water resembling gills.

Fourthly, an arterial system to convey the fluid thus elaborated to the various glands of the vegetable for the purposes of its growth, nutrition, and secretions; and a system of veins to bring back a part of the blood not thus expended.

Fifthly, the various glands which separate from the vegetable blood the honey, wax, gum, resin, starch, sugar, essential oil, and other secretions.

Sixthly, the organs adapted to the lateral or viviparous generation
of

of plants by buds, or to their sexual or oviparous propagation by seeds.

Seventhly, longitudinal muscles to turn their leaves to the light, and to expand or close their petals or their calyxes; and vascular muscles to perform the absorption and circulation of their fluids, with their attendant nerves, and a brain, or common sensorium, belonging to each individual seed or bud; to each of which we shall appropriate an explanatory section.

7. An embryo bud, therefore, whether it be a leaf-bud or a flower-bud, is the viviparous offspring of an adult leaf-bud, and is as individual as a seed, which is its oviparous offspring. It consists, first, of a central organization or caudex like the corculum of a seed, which contains the rudiments of arteries, veins, absorbent vessels, and glands, with an internal pith or brain.

Secondly, it is furnished with a system of umbilical vessels, which are inserted into the alburnum or sap-wood of the tree, or form a part of it, and descending into the earth supply it in the early spring with its first nutrition, like the feminal roots, so called, which pass from the corculum of the seed, and are spread on the cotyledons, as seen in the garden bean, represented in Plate I. Fig. 1. which is taken from Dr. Grew's Anatomy of Plants.

Thirdly, this umbilical system probably contains also what may be termed a placental artery, terminating on the coats of the lateral air-vessels, which penetrate the bark of trees horizontally, for the purpose of oxygenating the blood of the vegetable fetus, like those distributed from the umbilical vessels of the chick on the air-bag at the broad end of the egg. See Sect. II. 4. and III. 1—4.

Fourthly, it contains the rudiments of organs adapted to lateral generation or the production of new buds; or to sexual propagation, and the consequent production of seeds.

In the early spring the umbilical vessels supply the embryo buds of trees with sap-juice, which is then seen to exude from wounds of

the alburnum, as in the vine, *vitis*; the birch, *betula*; and the maple, *acer*; which I suppose to become oxygenated in the circulation of the vegetable fetus by the horizontal air-vessels of the bark.

As the season advances, the leaf-bud puts forth a plumula, like a seed, which stimulated by the oxygen of the atmosphere rises upwards into leaves to acquire its adapted pabulum, which leaves constitute its lungs; it also protrudes from its long caudex, which forms the new bark over the old one, a radicle, which stimulated by moisture passes downwards, and descends into the earth to acquire its adapted pabulum; and it thus becomes an adult vegetable being with the power of producing new buds.

The flower-bud under similar circumstances puts forth its bractes or floral-leaves, which serve the office of lungs to the pericarp and calyx; and expands its petals, which serve the office of lungs to the anthers, and stigmas, which are the sexual organs of reproduction, and which die and fall off, when the seed is impregnated; and thus, like the leaf-bud, it becomes an adult vegetable being with the power of producing seeds.

8. As the flower-bud produces many seeds during the summer, so the leaf-bud produces many budlets during the summer, as may be seen in the long shoots of the vine and willow, *vitis et salix*. In this climate both the buds and seeds are properly biennial vegetables; that is, they are produced in one summer, and perish in the next. But the seed differs from the bud in this circumstance, that it drops on the earth, and is thus separated from its dead parent in the autumn; whereas the bud continues to adhere to its dead parent, and grows over it as it advances.

Now as the internal pith of a bud appears to contain or produce the living principle, like the brain and medulla oblongata, or spinal marrow of animals, we have from hence a certain criterion to distinguish one bud from another, or the parent bud from the numerous budlets,

PLATE I.

PLATE I.

FIG. 1. represents the umbilical vessels spread on the lobes of a bean, when it begins to vegetate, as mentioned in Sect. I. 7. but more particularly described in Sect. III. 1. 3; which are believed to consist of a system of absorbent vessels, and another system of placental vessels, for the purpose of acquiring nutriment, and of oxygenating the vegetable blood. The plate is copied from Grew, Tab. I. *f.* 14. *a* the plumula, *b* the coraculum, *c c* the lobes. See Sect. I. 7. and III. 1. 3.

FIG. 2. is copied from Malpighi, Tab. II. Fig. 6, and represents the longitudinal fibres of the bark of willow, which adhere together, and separate from each other alternately, with horizontal apertures between them; which are believed to be air-vessels, for the purpose of oxygenating the blood of the embryo buds, like the air-bag at the broad end of an egg. *b b b* are the longitudinal filaments of the bark, *a a a* are the horizontal perforations.

Duhamel observed by a microscope similar apertures of different diameters in the bark of oak; the smaller ones he believed to be the excretory ducts of the perspirable matter, and larger ones I suppose to be air-vessels. The extremities of some of these in the birch-tree stood above the level of the cuticle. *Physique des Arbres*, Plate I. Fig. 7. and II. See Sect. I. 7. and II. 4. of this work.

Fig. 1.

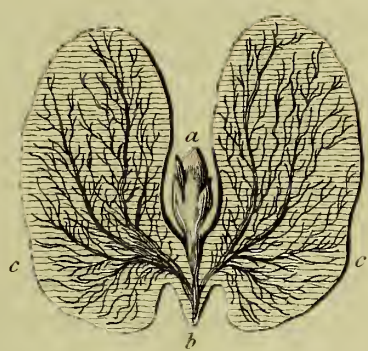


Fig. 2.



budlets, which are its offspring, as *there is no communication of the internal pith between them.*

This observation was made by flitting the young branches of horse-chestnut, *æsculus hippocastanum*; of ash, *fraxinus*; of willow, *salix*; and of elder, *sambucus nigra*; and I plainly discerned that there existed no communication of pith between the lateral budlets and their parent shoots, or between the central larger budlet at the summit of the branch, and its parent shoot. This also afforded me one reason to conclude that the different joints of wheat, *triticum*, of southistle, *fonchus*, and of teasel, *dypsacus*, are different buds growing on each other, those at the summit only producing seeds; because there is a division which separates the pith contained in each joint of their hollow stems, as is further explained in Sect. IX. 2. 4. and 3. 1. and which perfectly evinces the individuality of buds.

SECT. II.

THE ABSORBENT VESSELS OF VEGETABLES.

1. *Roots, leaves, bark, sap-wood, shewn to absorb by not moistening them, by placing them in water.* 2. *Absorbent vessels coloured by a decoction of madder, by dilute ink. They form a ring in the sap-wood beneath the bark, with a ring of arteries exterior to them.* 3. *Absorbents erroneously believed to be air-vessels, are visibly full of sap-juice in a vine-stalk. Vegetable vessels have rigid sides, which do not collapse, and hence become full of air when cut; not so in animal vessels.* 4. *Some horizontal vessels in trees are truly air-vessels for the embryo bud, like the air in the broad end of the egg.* 5. *Absorbent vessels consist of long cylinders; air will pass through them either way in the dead vegetable; are not respiratory organs, as they exist in the roots of trees. May receive air dissolved in water.* 6. *Absorbent vessels act either direct or retrograde. A forked branch in water. An inverted tree. A suspended tree. So in the operation of an emetic, and in ruminating cows.* 7. *They consist of a spiral line without valves; and by its vermicular contraction forcibly carry on their contained fluids either way.* 8. *Those of the root act occasionally in winter; but vines in hot-houses must have their roots guarded from frost in spring. Accumulated ice destroys trees in spring.* 9. *They sometimes absorb poisonous fluids, as spirit of wine, solution of arsenic, vitriolic acid; roots said to creep aside from bad soil erroneous.* 10. *Absorbents of trees like the receptacle of chyle.*

I. THE existence of that branch of the absorbent vessels of vegetables, which resembles the lacteals of animal bodies, and imbibes their nutriment from the moist earth, is evinced by their growth, so long as moisture is applied to their roots, and their quickly withering when it is withdrawn.

Besides

Besides these absorbents in the roots of plants there are others, which open their mouths on the external surfaces of the bark and leaves to absorb the moisture of the atmosphere, resembling the cutaneous lymphatics of animal bodies; the existence of these is shewn, because a leaf plucked off and laid with its under side on water will not wither so soon as if left in the dry air. The same if the bark alone of a branch, which is separated from a tree, be kept moist with water.

A third branch of absorbent vessels opens its mouths on the internal surfaces of the cells and cavities of the vegetable system to absorb the secreted fluids, after they have performed their adapted offices, similar to the cellular lymphatics of animal bodies, as may be shewn by moistening the alburnum or sap-wood, and the internal surface of the bark of a branch detached from a tree, which will not then so soon wither as if left in the dry air unmoistened.

Another means of demonstrating the absorbent powers of the parts of vegetables is by inserting them into glass tubes, or into tall narrow vessels filled with water, and observing how much more rapidly the surface of the water subsides than in similar vessels by evaporation alone.

2. By the following experiment these vegetable absorbent vessels were made agreeably visible by a common magnifying glass. I placed in the summer of 1781 some twigs of a fig-tree with leaves on them about an inch deep in a decoction of madder (*Rubia tinct*), and others in a decoction of logwood (*hæmatoxylum campechense*), along with some sprigs cut off from a plant of *picris*. These plants were chosen because their blood is white. After some hours, and on the next day, on taking out either of these, and cutting off from its bottom about an eighth of an inch of the stalk, an internal circle of red points appeared, which I believed to be the ends of absorbent vessels coloured red with the decoction, and which probably existed in the newly formed alburnum, or sap-wood, while an external ring of arteries was

seen to bleed out hastily a milky juice, and at once evinced both the absorbent and arterial system.

Many similar experiments were made by M. Bonnet, by placing parts of the stem or roots of various vegetables, as of kidney-beans, peach-tree, and elder, in dilute ink; in all these the vessels of the bark were uncoloured, and those of the pith; but those beneath the bark, which he terms woody, were coloured black, which I suppose to have been the circle of absorbent vessels above mentioned. *Usage de Feuilles*, Plate XXIX.

3. These absorbent vessels have been called bronchia by Malpighi and Grew, and some other philosophers, and erroneously thought to be air-vessels; in the same manner as the arteries of the human body were supposed to convey air by the antients, till the great Harvey by more exact experiments and juster reasoning evinced, that they were blood-vessels. This opinion has been so far credited because air is seen to issue from wood, whether it be green or dry, if it be covered with water, and placed in the exhausted receiver of an air-pump; and these vessels have therefore been supposed to constitute a vegetable respiratory organ; but it will be shewn hereafter, that the leaves of plants are their genuine lungs, and that the absorbent vessels and arteries become accidentally filled with air in the dead parts of vegetables.

For as the vessels of vegetables are very minute, and have rigid coats, their sides do not collapse when they are cut or broken, as their juices flow out or exhale; they must therefore receive air into them. This may be readily seen by inspecting with a common lens the end of a vine-stalk two or three years old, when cut off horizontally. At first the vessels, which are seen between the partitions radiated from the center, appear full of juice; but in a minute or less this juice either passes on, or exhales; and the vessels appear empty, that is filled with air. This experiment I have twenty times repeated with

with uniform success, and it is so easily made by hastily applying a common lens after the division of a vine-stalk, that I think there can be no error in it; and it is wonderful that these vessels, which are found in the alburnum, and consist of a spiral line, whether they may properly be called absorbent or umbilical vessels, or consist of both, should ever have been supposed to be air-vessels.

There is nevertheless an experiment by Dr. Hales, which would at first view countenance the assertion, that vegetables absorb air. He cemented the lower end of a small twig of a tree with leaves on it into a glass tube about four inches long, and set the other end of the tube an inch deep in water, and observed in a little time, that the water rose an inch in the tube; but this must happen from the vegetable vessels emptying themselves by the ascent of their juices, and having rigid coats, and therefore not contracting, a portion of the air was forced into them by the pressure of the atmosphere, as in the above observation on the vine-branch cut horizontally.

This reception of air does not happen to the vessels of animal bodies, when they are emptied of their blood, owing to the less rigidity of their coats; whence the weight of the atmospheric air presses their sides together, and closes the vessel, instead of passing into it. In the same manner no air would pass into the vessels of the lungs of animals in respiration, unless the pressure of the atmosphere on their sides was prevented by the action of the muscles, which enlarge the cavity of the thorax by elevating the ribs.

4. There are nevertheless certain horizontal vessels of large diameter, which pass through the bark of trees to the alburnum, which probably contain air, as they are apparently empty, I believe, in the living vegetable; for the bark of trees consists of longitudinal fibres, which are joined together, and appear to inosculate at certain distances, and recede from each other between those distances like the meshes of a net, in which spaces several horizontal apertures are seen to penetrate through the bark to the alburnum, according to Malpighi,

who has given a figure of them, which is copied in Plate I. Fig. 2. of this work. Very fine horizontal perforations through the bark of trees are also mentioned by Duhamel, which he believes to be perspiratory or excretory organs, but adds, that there are others of much larger diameter, some round and some oval, and which in the birch-tree stand prominent, and pierce the cuticle or exterior bark. *Physique des arbres*, T. 1. Tab. III. Fig. 8. and 11.

These vessels probably contain air during the living state of the tree, as they pierce the external bark, which frequently consists of many doubles, like a roll of linen cloth; as a new cuticle is annually produced beneath the old one, like a new scarf-skin beneath a blister in animal bodies; and the old one sometimes continues, and sometimes peels off like the cuticle of a serpent, as is seen on the trunks of many cherry-trees and birches. These vessels, when contracted in dry timber, appear like horizontal insertions in many planed boards, in which the spiral absorbent vessels become by their contraction the longitudinal fibres, as appears in the figure of a walking cane given by Dr. Grew, Tab. XX.

These horizontal vessels I suppose to contain air inclosed in a thin moist membrane, which may serve the purpose of oxygenating the fluid in the extremities of some fine arteries of the embryo buds, in the same manner as the air at the broad end of the egg is believed to oxygenate the fluids in the terminations of the placental vessels of the embryo chick, as further noticed in Sect. III. 2. 6. and III. 1. 4.

5. The absorbent vessels of trees in passing down their trunks consist of long hollow cylinders, whose sides I believe to be composed of a spiral line, and are of such large diameters in some vegetables as to be visible to the naked eye, when they become dry and empty, as in cane. Air will rapidly pass through these vessels in either direction, as may be seen in lighting a cane some inches long at either end, and drawing the smoke through the pores of it into the mouth, as through a tobacco-pipe. Dr. Hales readily passed both air and water through
a recent

a recent vegetable stick both upwards and downwards, by setting one end of it in a cup of water in the receiver of an air-pump, and exhausting the air, Veg. Stat. p. 154; whence he concludes with Grew, that these are air-vessels or lungs for the purpose of respiration, and that they receive atmospheric air in their natural state.

There is one objection to their use as air-vessels, which is, that they have no communication with the horizontal air-vessels above described; for by blowing forcibly through a piece of dry cane immersed deep in water, no air is seen to bubble out of the sides, but only from the bottom of it. It may indeed be supposed, that the longitudinal cavities in dry cane may not consist of the absorbent vessels above described, but of the interstices between them, as the coats of those absorbent vessels, consisting of a spiral line, may be thought to close up by their vermicular contraction; and their interstices, consisting of vegetable cellular membrane, may be supposed, when dry, to become the tubes in cane. But in this case the longitudinal canals in dry cane would not be circular cylinders, whereas they are so represented in a figure of a piece of cane much magnified by Dr. Grew, Tab. XX. who has in the same figure given the mouths of horizontal air-vessels of circular form and larger diameter.

But there is another insuperable objection to this idea of their use, which is, that these vessels equally exist in the roots of plants as in their trunks; and according to Malpighi with larger diameters; and probably terminate externally only in the roots; and, as they are there not exposed to the atmosphere, they cannot serve the purpose of respiration; air nevertheless in its combined state, or even as dissolved in water, may be absorbed by these vessels; and may appear, when the pressure of the atmosphere is removed in the exhausted receiver; or when expanded by heat, as is seen in the froth at one end of a green stick, when the other end is burning in the fire.

6. These vegetable absorbents differ from those of animals in the facility, with which they carry their fluids either way; for a forked
branch

branch of a tree, torn from its trunk, and having one of its forks with the leaves on it inverted in a vessel of water, will continue for several days unwithered, nearly as well as if the whole had been placed upright in the water. A willow rod on the same account will grow almost equally well, whether the apex or base of it be set in the ground; and Dr. Bradley, I think, mentions a young gooseberry-tree having been taken up, and replanted with its branches in the earth, and its roots in the air; and that the branches put forth root-fibres, and the roots put forth leaf-buds. There is likewise a curious experiment by Dr. Hales, who attached the eastern branch of a young tree to its neighbour by inarching, and its western branch to another of its neighbours in the same manner; and after they were united, he cut the stem of the middle tree from its root, and thus left it hanging in the air by its two inarched arms, where it flourished with considerable vigour.

This power of carrying their fluid contents in a retrograde direction is also possessed in some degree by the absorbents of animals, particularly in their diseased state, and even in the operation of an emetic, as shewn in *Zoonomia*, Vol. I. Sect. 29; and is visible in the oesophagus or throat of cows, who convey their food first downwards, and afterward upwards by a direct and retrograde motion of the annular cartilages, which compose the gullet, for the purpose of rumination.

7. The structure of these large vegetable absorbents, erroneously called air-vessels, probably consists of a spiral line, and not of a vessel interrupted with valves, and differs in this construction from animal lymphatics; for first, on breaking almost any tender vegetable, as a last year's sprig of a rose-tree, or the middle rib of a vine-leaf, and gradually extending some of the fibres, which adhere the longest, this spiral structure becomes visible even to the naked eye, and distinctly so by the use of a common lens, as is delineated in Duhamel's *Physique des arbres*, T. 1. Tab. II. Fig. 17, 18, 19, and in Plate LI.
and

and LII. of Grew's Anatomy of Plants (fol. edit.), and by this easy experiment both that absorbent system, which imbibes nourishment from the earth, and brings it to the caudex of each bud; and that which imbibes moisture from the air, and a part of the perspirable matter on the surface of the leaf, and brings it to the caudex of each bud, are agreeably demonstrated. See Plate II. Fig. 1. And that these vessels of large diameter, with their sides consisting of a spiral line, are not arteries or veins, is evinced by inspecting a stem of euphorbia, spurge; or the stalk of a fig-leaf, ficus, immediately on dividing them, as the milky juice oozes from a ring of vessels exterior to those large absorbents.

Secondly, that these vessels are not furnished with frequent valves is countenanced by the experiments before mentioned in No. 5 of this section, one of which consisted of lighting a piece of cane, and drawing the smoke through it, as through a tobacco-pipe, in either direction; and the other in placing a bit of recent twig with one end of it in a cup of water in the receiver of an air-pump, and causing both air and water to pass through it in either direction.

If the minuter branches of vegetable absorbents be of a similar structure, it is easy to conceive how a vermicular or peristaltic motion of the vessel, beginning at the lowest part of it, each spiral ring successively contracting itself, *till it fills up the tube*, must forcibly push forwards its contents without the aid of valves; and if this vermicular motion should begin at the upper end of the vessel, it must with equal facility carry its contained fluid in a retrograde or contrary direction.

8. As the absorbent vessels in the roots of plants are protected from the frost in some degree by the earth which covers them; they seem at all times to be sufficiently alive to drink up and push forwards their adapted fluid, since if a branch of a tree is brought into a warm room, it will in general pullulate in the winter, as soon as the vessels of the upper part of the branch are rendered sufficiently irritable by warmth to act in concert with the absorbents of the root,

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Nevertheless,

Nevertheless, in severe frosts it is necessary to guard all the parts of the stem which is exposed to the open air, as is experienced in the vines brought through holes into hot-houses, otherwise after the buds are put out a severe frost so affects the stems on the outside of the house as to destroy all the fruit of that year. Kenedy on Gardening, Vol. I. p. 270. And it is observed in Mr. Aikin's Natural History of the Year, that much ice was carried from the streets in London in 1794, and piled round some elm trees in Moorfields, many of which were destroyed in the ensuing spring by the slow melting of it.

9. The absorbent vessels of vegetables, like those of animal bodies, are liable to err in the selection of their proper aliment, and hence they sometimes drink up poisonous fluids, to the detriment or destruction of the plant. Dr. Hales put the end of a branch of an apple-tree, part of which was previously cut off, into a quart of rectified spirit of wine and camphor, which quantity the stem imbibed in three hours, which killed one half of the tree. Veg. Stat. p. 43. Some years ago I sprinkled on some branches of a wall-tree a very slight solution of arsenic, with intent to destroy insects; but it at the same time destroyed the branches it was thrown upon. And I was informed by Mr. Wedgewood, that the fruit-trees planted in his garden near Newcastle in Staffordshire, which consisted of an acid clay beneath the factitious soil, became unhealthy as soon as their roots penetrated the clay; and on inspection it appeared, that the small fibres of the roots, which had thus penetrated the clay, were dead and decayed, probably corroded by the vitriolic acid of the clay, beneath which is a bed of coals.

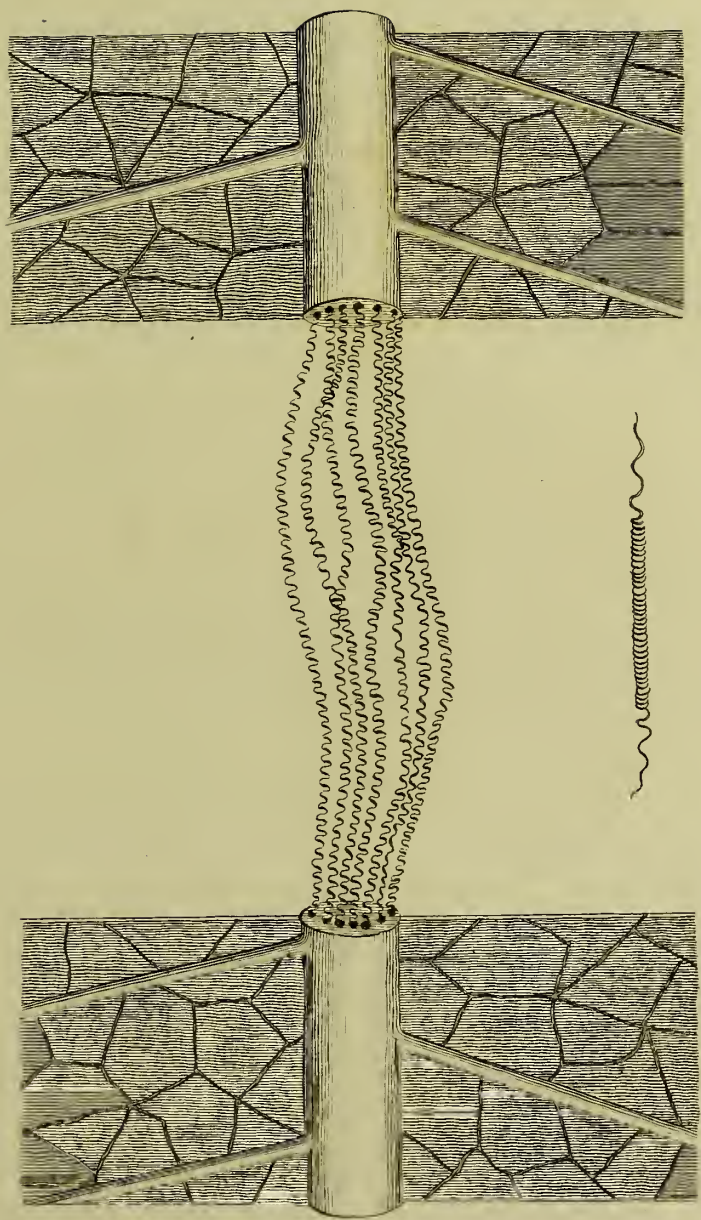
It is, however, asserted by M. Buffon, that the roots of many plants will creep aside to avoid bad earth, or to approach good. Hist. Nat. Vol. III. But this is perhaps better accounted for by supposing, that the roots put out no absorbent vessels, where they are not stimulated by proper juices; and that an elongation of roots in consequence only succeeds, when they find proper nutriment.

10. These long and large cylindrical absorbent vessels, which pass
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PLATE II.

PLATE II.

Represents the spiral vessels of a vine-leaf considerably magnified, copied from Grew, Tab. LI. On slowly tearing asunder almost any tender vegetable shoot or leaf, the spiral structure of these vessels becomes visible to the naked eye. They have been erroneously believed to be air-vessels; but as they exist equally in the roots of plants, as in their barks, and have no communication with the horizontal perforations of the cuticle of the bark, they cannot be air-vessels, and are therefore believed to constitute the absorbent vessels of the adult vegetable, and the umbilical ones of the embryo bud. A similar plate of the spiral structure of these vessels is given by Duhamel. As they are larger than the vegetable blood-vessels, and pass along the whole caudex of each bud from its plumula to its radicle, as well as to the cutaneous absorbents, those of the trunks of trees or herbaceous plants may be thought to resemble the receptaculum chyli of animal bodies. See Sect. II. 7.



from the roots of trees up to the summit of the caudex of each bud at the foot-stalk of the leaf, I suppose to be analogous to the receptacle of the chyle of animals, as the small absorbent branches of the roots probably unite beneath the soil into those large vessels, which are so easily visible; hence the caudex of each bud consists of an elongation of absorbent vessels, and of arteries and veins reaching from the union of the root-branches to the foot-stalk of each leaf, and the plumula of the bud in its bosom, as described in Sect. I. 7.

S E C T. III.

THE UMBILICAL VESSELS OF SEEDS AND BUDS.

- I. 1. Seeds are a sexual offspring like eggs. Some seeds and eggs contain two kinds of nourishment. Other seeds and spawn of fish contain but one kind of nourishment. 2. Air-bag in eggs, and in some fruits; not in seeds, nor in spawn. 3. Vessels improperly called umbilical; those properly called umbilical consist of absorbents, and a placental artery and vein. Seed embryo and chick begin their growth by the action of their absorbents. 4. Seminal roots of Grew, and chorion of the chick of Malpighi, are respiratory organs. 5. In what the chick differs from the seed-embryo. Nothing is found in seeds similar to the yolk of the egg. II. 1. Buds and bulbs are a paternal offspring; exactly resemble their parents. 2. Have umbilical vessels, in which the sap-juice rises in the spring. Why the bark is then easily separated from the alburnum. 3. Sugar in the sap-juice exists in the alburnum, and in roots. Dry rot of timber owing to fermentation. Why lower branches first pullulate. 4. Sap ascends not by capillary attraction, but by the irritative motions of absorbent vessels. Instances of vegetable irritability. Absorbent vessels sometimes act as capillary syphons, and as capillary tubes. 5. Umbilical vessels coalesce. Why trees do not bleed in summer. 6. Umbilical vessels of buds like those of seeds. Possess air-vessels like those of the chick. Buds, like eggs, separate from the parent; their umbilical vessels improperly called placental ones, as they convey nutriment; hence plants become dwarfs if the cotyledons of the seed are destroyed. Birch-trees die if smeared with oil or pitch. 7. Reservoir of nutriment in the alburnum of trees, and in the roots of biennial plants. Experiment of boiling the alburnum and fermenting the liquor. As buds are formed at midsummer, they may then be transplanted by inoculation, but in the spring must be ingrafted, and grow by insculcation of vessels, like inflamed parts of animals. 8. A pause in vegetation at midsummer. New umbilical vessels act in autumn, and the bark separates easily as in spring. Honey-dew. Sap-juice rises in winter occasionally both in
ever-

ever-green trees and deciduous ones, and after the summit of the plant is cut off.

9. *Umbilical vessels and absorbents seen in a vine-stalk, the latter exterior to the former. Exist in the alburnum.*

I. 1. THE seeds of vegetables are a sexual offspring corresponding with the eggs of animals, and contain, like them, not only the rudiment of the new organization, but also a quantity of aliment laid up for its early nourishment.

The eggs of birds contain two kinds of albumen, or white, one less viscid than the other, which is first consumed, and the yolk or vitellum, which is drawn up into the bowels of the chick at its exclusion from the shell, and serves it for nourishment a day or two, till it can learn to select and digest grains or insects. In like manner many seeds are furnished with two kinds of nourishment, the mucilaginous or oily meal of the seed-lobes, and the saccharine or acescent pulp of the fruit, as in pears, plums, cucumbers, which supply nutriment to the embryo plant, till it is able to strike into the earth sufficient roots for the purpose of absorbing its nutritious juices.

The spawn of fish, and of frogs, and of insects, as of snails and bees, which are almost as innumerable as the seeds of plants, and are in the same manner excited into life by the warmth of the sun, are analogous to those seeds, I believe, which are not surrounded with fruit, and which contain but one kind of nourishment for the embryo plant, as grains of corn, and legumes; but perhaps these have not yet been sufficiently attended to by philosophers.

These eggs of animals and seeds of vegetables are produced by the congress of male and female organs; the former supplying the speck of animation or cicatrix in the egg, and the corculum or heart in the seed; and the latter producing the nidus, or nest for its reception, and the nutritive material for its first support. Thus the eggs of fowls are formed long before they are impregnated, and are sometimes laid in their unimpregnated state; and the seeds of legumes are
visible

visible many days before the flower opens, and in consequence before they are impregnated, as observed by Spallanzani.

2. The eggs of birds contain a bag of air at their broad end for the purpose of oxygenating the blood of the chick. In this one circumstance the seeds of plants seem to differ from the eggs of birds, as they contain no air-bag, though it is probable they may agree with the spawn of fish, which I suppose possess no included air. When the seeds fall on the ground in their natural state of growth, or are buried an inch or two beneath the soil, which has recently been turned over, and thus contains much air in its interstices, their coats do not continue dry like the shells of eggs during incubation, but immediately become moist membranes, like the external membrane of the spawn of fish immersed in water, and in consequence can admit the oxygenation of the air through them to an adapted set of arteries on their internal surface, according to the curious observations of Dr. Priestley on the oxygenation of the blood by the air through the moist membranes of the lungs.

It should be here observed, that many seeds, before they fall on the moist earth, are included in a bag of air, as those of the *staphylea*, bladder-nut; of the *physalis alkekengi*, winter-cherry; of *colutea*, bladder-fenna; in the pods of peas and beans; in the cells surrounding the seeds of apples and pears; and in the receptacle of *ketmia*, which probably serves to oxygenate the blood of the infant seed, which in these plants may thus be of forwarder growth, before it is shed upon the soil.

3. There exists a series of glands, and their ducts, improperly called umbilical vessels by some writers, which supplies the seed with nourishment from the parent plant, so long as it adheres to the ovary of its mother, as the vessels by which a pea adheres to the pod, in which it is included; in fruits and nuts, where the kernel is covered with a stone or shell, a long cord of vessels passes into the bottom of the stone or shell, and rising to the top bends round the lobes of the kernel,

nel, and is inferted near or into the corculum or heart of the feed, where the living principle refides, and affords not only prefent nutrition to the vegetable embryo, but alfo fecretes the farinaceous or oily materials for its future nourifhment, which conftitute the cotyledons of the feed.

But the veffels, which may be properly called umbilical, pafs from the heart or corculum of the feed, which is the living embryo of the future plant, into the feed-lobes, commonly called cotyledons, and imbibe from thence a folution of the farinaceous or oily matter there deposited for the nutriment of the new vegetable. Thefe veffels are delineated in their magnified appearance by Dr. Grew, Plate LXXIX. fol. edition, and are by him termed feminal roots. See Plate I. Fig. 1.

Thefe umbilical veffels probably confift of a fyftem of abforbents, which fupply nutriment to the embryo plant from the cotyledons of the feed, and alfo of a fyftem of placental arteries and veins fpread on the humid membrane, which covers the cotyledons, and is moiftened by its contact with the earth, for the purpofe of oxygenating the vegetable blood. This idea is countenanced by many plants bringing up their cotyledons, or feed-lobes, out of the ground into the air, which are then converted into leaves, and perform the office of lungs, after they have given up beneath the foil the nutriment, which they previoufly contained, as in the young kidney-bean, *phafeolus*; fo the white corol of the *helleborus niger*, christmas rofe, is changed into a green calyx by loofing one fyftem of arteries after the impregnation of the feeds.

The feed-embryo therefore refembles the chick in the egg, firft as when vivified by the influence of external warmth they both begin their growth by the abforbent fyftem of veffels being ftimulated into action by their adapted nutriment; and the fluids thus pushed forwards ftimulate into action the other parts of the fyftem, confifting at firft principally of arteries and glands.

Secondly, they feem to refemble each other in their poffeffing each
of

of them an absorbent system of vessels, which imbibe the nutritious matters laid up for them in the albumen or white of the egg, and in the cotyledons or lobes of the seed; and also of a placental system of arteries for the purpose of oxygenating their fluids, as described above in the seed, and which appears in the egg to be spread on a membrane, which covers the white, as is shewn in the plates of Malpighi, and called by him the chorion, and exposes the blood of the chick to the oxygen of the air contained at the broad end of the egg through a moist membrane.

4. The use of the large apparent artery spread on the cotyledons of a germinating seed of a garden-bean, called seminal roots by Grew, as shewn in Plate I. Fig. 1, and that spread on the chorion of the chick in the egg, so called by Malpighi, and shewn in Tom. II. Fig. 54, and by Fabricius ab Aquapendente, Tab. I. Fig. 13, which must be an artery, as it carries red blood, are believed to be respiratory organs, like the placental vessels of the fetus of viviparous animals, because the cotyledons of some seeds rise out of the ground, and become leaves, after the nutriment they contained is expended, and are then called seminal leaves, as in the kidney-bean, *phaseolus*; and because those which do not rise out of the ground perish beneath the soil, as soon as the young plant gains its leaves, which are its aerial respiratory organ.

Secondly, the chorion of the chick consists of a membrane including the white, or albumen, and is not only in contact with the air-bag at the broad end of the egg, which, as the chick advances, covers more than half of the internal surface of the shell, but also with the membrane which lines all the other part of the shell, as appears in Plate III. which is copied from Malpighi: yet this extensive chorion, with the numerous arteries and veins which are spread upon its surface, is not drawn up into the body of the chick like the yolk and its including membrane, but perishes at the nativity of the chick like the placental vessels of the fetus of viviparous animals; or sometimes,

times, I suppose, before its nativity, as the chick perforates the air-bag, and is heard to chirp, before it is excluded from the shell.

Hence it would appear, that both the artery attending the feminal roots above mentioned, and this artery on the chorion of the chick, must perform some more important office than to supply nourishment to the coats of the absorbent vessels, which imbibe the mucilage of the feed, or the white of the egg, and which absorbents must themselves possess their proper *vasa vasorum*. And what more important office can they have than that of oxygenating the blood of the vegetable or animal embryo? And this becomes more probable as they both perish at its nativity like the placenta and cotyledons of viviparous animals.

5. As the incubation of the chick advances, it differs from the feed-embryon in the production of intestines, with a stomach, on the internal surfaces of which the mouths of the absorbents now terminate; and lastly in the production of a mouth and throat to receive and swallow the remainder of the albumen, in which it swims; whereas the feed-embryon shoots down new roots into the earth with an absorbent system to acquire its nutriment, as that from the cotyledons of the feed becomes exhausted. See Sect. VII. 1, 2.

Nor is there any thing similar to the yolk of the egg found in the feeds of vegetables, which is drawn up into the intestines of the young chick about the time of its exclusion from the shell to serve it with nutriment for a day or two, till it can learn of its parent by imitation to select and swallow its adapted food. Nor is the fetus of viviparous animals furnished with any thing similar to the yolk of oviparous ones, as they have milk ready prepared for their first nutriment in the breast of the mother.

As soon as the new foliage of the plant rising out of the ground becomes expanded, and the root descending penetrates the earth with its fibrous ramifications, the umbilical systems of vessels cease to act, both the absorbents, which previously supplied the young embryo

with nutriment from the cotyledons, and also the placental artery, which was spread on the exterior membrane of the cotyledons for the purpose of oxygenation. These vessels now either coalesce and decay beneath the soil, or wither and fall off, when raised above it in the form of seed-leaves.

II. 1. The seeds of plants are thus a sexual or amatorial progeny, produced principally by the male part of the flower, and received into a proper nidus, and supplied with nutriment by the female part of it, and which can thus claim both a father and a mother. But the buds of vegetables are a linear pogeny, produced and nourished by a father alone, to whom they adhere, not falling off like the seeds, as is farther treated of in *Zoonomia*, Vol. I. Sect. XXXIX. II. 2. and in Sect VII. I. 3. of this work. For in this most simple kind of vegetable reproduction, by the buds of trees, and by the bulbs of some plants, and by the wires of others, which are their viviparous progeny, the caudex of the leaf is the parent of the bud or bulb, or wire, which rises in its bosom, according to the observation of Linneus.

This linear or paternal progeny of vegetables in buds or bulbs, or wires, is attended with a very curious circumstance, which is that they exactly resemble their parents, when they are arrived at their maturity, as shewn in Sect. VII. 1. 3. as is observed in grafting fruit-trees, and in propagating flower-roots, or strawberries, or potatoes, by their wires or roots; whereas the feminal offspring of plants, as it derives its form in part from the mother as well as father, is liable to perpetual variation, both which events are employed to great advantage by skilful gardeners.

2. As the embryos in the buds are the viviparous offspring of vegetables, it becomes necessary, as they have no mouths, that they should be furnished like the embryos in the seeds with umbilical vessels to supply them with nourishment, till they acquire roots with another set of absorbent vessels to imbibe moisture from the earth, and leaves to act like lungs for the purpose of oxygenating their blood.

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These umbilical vessels, which supply the buds of plants with nourishment in the early spring, and unfold their foliage, have been much attended to by Dr. Hales and Dr. Walker (Edinb. Phil. Transact. Vol. I.) The former observed, that the sap from the stump of a vine, which he had cut off in the beginning of April, arose twenty-one feet high in glass tubes affixed to it for that purpose, but which in a few weeks ceased to bleed. Dr. Walker also marked the progress of the ascending sap in various branches of trees, and observed, that in cold weather it stopped many hours in a day, as well as in the night, and found likewise as soon as the leaves became expanded, that the wounded trees ceased to bleed.

The vessels, which convey the sap-juice with such amazing force, are situated in or compose the alburnum, or sap-wood, of the trunk or root of the tree; nor is it surprizing, that some of it when pressed by so high a column should exsude into the cells between the alburnum and bark, as in these cells much sap-juice was observed by Dr. Walker, and this accounts for the great ease with which the barks of willows and of oaks are separated in the spring from their wood. The absorbent mouths of these sap-vessels open externally in the moist earth on the roots of trees, and also into the air on their trunks; and thus mix the aqueous fluids, which they thus imbibe, with the saccharine and mucilaginous materials deposited previously in the alburnum of these roots and trunks.

3. This ascending sap-juice during the spring season is in some trees so sweet, that it is used in making wine, as that of the birch-tree in this country; and sugar is procured in such quantity from a maple in Pennsylvania, that from each tree five or six pounds of good sugar have been made annually without destroying it. Rush, on Sugar Maple. Phillips, London. This sugar is deposited I believe in the sap-wood of the trunk and roots of trees, as in the manna-ash, and is dissolved in the spring by the moisture, which is drank up by the absorbents from the earth and atmosphere, and forcibly carried on to

expand the buds. Its existence in the sap-wood as well as in the roots is shewn from the pullulation of oak-trees, which have been stripped of their bark, and also from the expansion of the eyes of a vine-shoot, when it is cut from the tree, and planted in the earth, as described in Sect. XV. 1. 3.

This suggests to us the reason why the wood of trees is so much sooner subject to decay, when they are felled in the vernal months; because the sugar, which the sap-wood then contains, soon runs into fermentation, and produces what is called the dry rot; whence the custom has prevailed of debarking oaks in the spring, and felling them in the autumn; and it is probable that the wood of all other trees would last much longer, if it was thus managed, as the growth of the new leaves would exhaust the sugar of the sap-wood.

Sweet juices for a similar purpose of expanding the buds of herbaceous plants are deposited during the autumn in their roots, as in turnep, beet, tragapogon; or in the knots or joints of the stem, as in grasses, and the sugar-cane; which like the farina and oil in seeds, and the dulcet mucilage of fruits, and the honey of flowers, were designed for the food of the young progeny of plants, but become the sustenance of mankind!

As the saccharine matter which is thus deposited in the roots, or in the alburnum, or in the joints of plants, must be diluted by the moisture absorbed from the earth by their roots, we understand why the leaves of the lower branches of trees are first expanded, as is seen distinctly in the hawthorn hedges in April, as these must first receive the ascending sap-juice, as was observed by Dr. Walker in his account of the maple.

4. The force of the rising sap from a vine-stump in the bleeding season, as discovered by Dr. Hales, is at some times equal to the whole pressure of the atmosphere, which is about fourteen pounds on a square inch of surface. This great power in raising the sap he ascribes to capillary attraction, and to the variations of heat during the day

day and night. In regard to capillary attraction, however high it may raise a fluid in very small tubes, it can not make it flow over them, as the sap-juice did in Dr. Hales's vine-stump; nor can it raise a fluid quite to a level with the upper rim of a glass tube, as the fluid is there more attracted downwards by the glass besides its gravity, and is left in consequence with a concave surface.

The means by which vegetable absorbent vessels in their living state imbibe the fluids of the earth and atmosphere, and carry them forwards with so much force, must be similar to those, with which animal absorbent vessels perform the same office; that is by their mouths being excited into action by the stimulus of the fluids, which they absorb.

This circumstance is confirmed by the evident proofs of the irritability of plants in various other instances, as the closing and opening of the petals and calyxes of flowers by light and darkness, warmth and cold, dryness and moisture, and by the motions of the leaves of mimosa, or sensitive plant, and of *dionœa muscipula*, by any mechanical stimulus. To this might be added a variety of instances of the irritability of vegetables to the stimulus of heat, being increased after a previous exposure to cold, exactly in the same manner as happens to animal bodies, which are enumerated in a note in the Botanic Garden, Vol. I. Canto I. l. 322, whence the reciprocal times of the acting and the ceasing to act of these vernal vegetable absorbents, which are here termed umbilical vessels, in the experiments both of Dr. Hales and Dr. Walker, may be readily explained by their having been benumbed by the cold, or excited into action by the warmth of the air or earth. See Sect. XIII. 2. 3.

From one experiment nevertheless of Dr. Walker's these vessels occasionally act as capillary syphons, because when he bent down a branch much lower than its origin from the tree, and cut off the end of it in the bleeding season, the sap flowed from the extremity of this branch so bent down, when some wounds two or three feet
lower

lower than the origin of this branch did not bleed. This may be accounted for from the ascent of the fluid in these vessels being at this time principally owing to the action of their absorbent mouths, and to their consisting of long cylinders with minute diameters and rigid coats, like those which are visible to the eye in dry cane, through which smoke will pass in either direction, and which at this early season may not be excited into vegetable action; there is nevertheless a power of absorption existing in any part of them in the warmer season, because a branch or flower-stalk cut from the root, and set in a glass of water, will drink up a considerable quantity of it. There is also a situation in their diseased or dead state, where they appear to act for some years like capillary tubes, as in the decorticated part of a pear-tree, described in Sect. XV. 2, 3.

5. During the great action of these umbilical absorbent vessels the buds become expanded, that is the young vegetable beings put forth leaves, which are their lungs, and consist of a pulmonary artery, vein, and absorbents, and also acquire a new bark over that of the branches, trunk, and roots, of the last year, which consists of aortal arteries, veins, and absorbents, and new radicles, which terminate in the soil. At this time the umbilical vessels, which existed in the alburnum, or sap-wood, cease to act, and coalesce into more solid wood, perhaps simply by the contraction of the spiral fibre, of which they are composed; and the swarm of new vegetables, which constitute a tree, are now nourished by their proper lacteal and lymphatic systems.

A curious circumstance now occurs, which is that wherever a tree is now wounded, no moisture appears. On the contrary, the wound from Dr. Hales's experiments is in a strongly absorbing state, inasmuch that on applying water to wounds made in the summer season, it was found to be drank up with great force, as was ingeniously shewn by mercurial syphons contrived to resist its absorption.

This evinces, that though during the bleeding season in the vernal months the sap-juice is imbibed by the umbilical absorbents, and carried

ried upwards probably by the annular contraction of the spiral fibres, which I believe compose these absorbent vessels, in such quantities as to bleed wherever the alburnum is exposed or wounded, yet that afterwards the exhalation by the numerous leaves becomes so great, that the actions of the new radical and lateral absorbents do not supply a fluid so fast, as it could otherwise be expended in the growth of the plant, or dissipated into the air; and as the vessels, which pass down the trunks of trees, inosculate in variety of places, as is seen in the cloth made at Otaheite from the bark of a mulberry-tree, when a wound is made through some of these vessels, the fluid, which might otherwise ooze out, is carried away laterally by those in their vicinity; and as the vessels of vegetables are rigid, and do not collapse when wounded like those of animals; and as the circulation in them is comparatively slow, but little of their contained fluids are poured out of them when wounded in the summer months.

6. From all these observations it finally appears, that the umbilical vessels of each bud are similar to those of a seed, which are called by Dr. Grew seminal roots, and that like the umbilical cords, which form the wires of strawberries above ground, and of potatoes under ground, they supply the new vegetable with nutriment, till the leaves are expanded in the air, and new roots are pushed out and penetrate the earth.

There is also a curious analogy between these umbilical vessels of buds, which exist in the alburnum of trees, and those belonging to the chick in the egg, which consists in their both possessing certain air-vessels; those of trees pass horizontally from the bark to the alburnum, and that of the egg exists at the broad end of it. Thus it is probable, that the fluid in the fine extremities of the new vessels of the embryo bud becomes oxygenated by these horizontal air-vessels, in the same manner as the fluid in the terminations of the arteries on the chorion of the chick is believed to become oxygenated by the air contained

contained at the broad end of the egg, as alluded to in Sect. II. 4. and III. 1. 4.

A circumstance, in which the bud may be conceived to differ from the egg, consists in the separation of the egg from its parent, as soon as the fetus has acquired a certain maturity, along with its umbilical vessels, and its reservoir of nutriment. But in vegetables something similar occurs, for the parent bud is separated by death in the autumn from its embryo offspring; the leaf falls off, which was the lungs of the parent bud, and the vessels of its caudex, which formed the bark, coalesce into alburnum, or sap-wood, surrounding the umbilical vessels of the new bud; which thus may be said to loose its parent like the egg, but retains its umbilical vessels, and a reservoir of nutriment, which exists in the sap-wood, and also another system of vessels, which constitute the new bark of the tree, consisting of the interwoven caudexes of each individual new bud.

But as the umbilical vessels of plants above described, which constitute the alburnum of the trunks of trees, and the seminal roots, so called, of the growing seed, convey nutriment to the embryo bud, or to the rising plumula, as well as oxygenation, they are not similar in that respect to the placenta of the animal fetus, and were improperly called placental vessels in the notes to the Botanic Garden, as the placenta of the animal fetus is shewn in Zoonomia, Vol. I. Sect. XXXVIII. to be an organ of respiration only, like the gills of fish, and not an organ for nutrition.

Hence when the cotyledons of seeds are cut away from the rising plume, the plant becomes a dwarf for want of nutriment; and the wounding or exposing the alburnum of bleeding trees, as of the birch or maple, in the vernal months to obtain the sap-juice retards the expansion of the new buds, and the consequent growth of the tree. Hence also it appears, why smearing the bark of a tree with pitch, or oil, or paint, is liable to destroy the new buds, and consequently the

tree,

tree, by stopping up their spiracula; and why covering an egg with greafe or varnish is said to prevent the production of a chicken, by preventing a change of air at the broad end of it.

7. We may conclude that the umbilical vessels of the new bud are formed along with a reservoir of nutritious aliment about midsummer in the bark, which constitutes the long caudex of the parent bud, in the same manner as a reservoir of nutritious matter is formed in the root or broad caudex of the turnep or onion, for the nourishment of the rising stem. And that these umbilical vessels of the embryo bud, and the reservoir of nutriment laid up for it, which is secreted by the glands of the parent bud, and now intermixed with the present bark of the tree, become gradually changed into alburnum, or sap-wood, as the season advances, in part even before the end of summer, and entirely during the winter months.

That the alburnum of trees, which exists beneath the bark both of the trunk and roots of them, contains the nutritious matter deposited by the mature leaves or parent buds for the use of the embryo buds, appears not only from the saccharine liquor, which oozes from the wounds made in the vernal months through the bark into the alburnum of the birch and maple, *betula et acer*; but also from the following experiment, which was conducted in the winter before the vernal sap-juice rises.

Part of a branch of an oak-tree in January was cut off, and divided carefully into three parts, the bark, the alburnum, and the heart. These were shaved or rasped, and separately boiled for a time in water, and then set in a warm room to ferment; and it was seen that the decoction of the alburnum or sap-wood passed into rapid fermentation, and became at length acetous, but not either of the other, which evinces the existence both of sugar and mucilage in the alburnum during the winter months; since a modern French chemist has shewn by experiments, that sugar alone will not pass into the vinous fermentation, but that a mixture of mucilage is also required; and

from this experiment it may be concluded, that in years of scarcity the sap-wood of those trees, which are not acrid to the taste, might afford nutriment by the preparation of being rasped to powder, and made into bread by a mixture of flour, or by extracting their sugar and mucilage by boiling in water, as mentioned in *Zoonomia*, Part III. Article I. 2. 3. 6.

Now as the embryo buds of deciduous trees of this climate are formed about midsummer, secreted by the generative glands in the caudex of the parent leaf-bud, and are supplied with due nourishment from the same source, not having yet shot out radicles of their own from the lower end of their long caudexes into the earth, they may be readily transplanted at this season from one tree to another by inoculation, or into different parts of the same tree; as the new caudex of the young bud of one tree will readily unite with the new caudex of that of another tree, and as they can be removed entire during the early state of their growth along with a part of the bark only, as scarcely any alburnum is yet formed beneath the bark of the young twig, from whence the bud is cut or torn.

But after their greater maturity, so that many buds exist on one twig, or scion, and are already furnished with radicles passing down into the ground, as in the ensuing spring, it becomes necessary to ingraft them by cutting off a part of the alburnum, as well as of the bark of the new bud; and to apply these in contact with the bark and alburnum of another tree, to which they may grow by inosculation of vessels; whence it appears why budding or inoculation must be performed soon after midsummer, and ingrafting in the early spring, as in the former the buds continue to grow by the junction of the caudex or bark vessels alone with those of the tree into which they are inserted, and in the latter by the inosculation of their vessels with those of the bark and alburnum of the tree, to which they are applied and bound.

The inosculation of the vessels of a bud cut out of one tree and inserted into the bark and alburnum of another, as in the ingraftment of scions, is exactly resembled by a similar operation on animal bodies, when a tooth is taken from one person and inserted into the head of another, and where two inflamed parts grow together. Thus an experienced anatomist is said to have cut the two spurs from a young cock, and applied them to the opposite sides of his comb, which was previously excoriated, where they continued to grow and appeared like horns; and Talicotius, whose book lies by me, seriously asserts, that he succeeded in making artificial noses from a part of the skin of the arm of his patients, and has published prints of the manner of the operation, so ridiculed by the author of *Hudibras*. *Cheirurgia Casparis Talicotii*.

The growth of an inoculated bud on the bark of another tree, where the upper part of the caudex of the inoculated bud joins with the lower part of the caudex of another bud belonging to the stock, is still more nicely resembled by the union of the head and tail part of two different polypi in the experiment of Blumenbach, mentioned in Sect. VII. 3. 2. of this work.

8. As the leaves of trees become expanded, the sap-juice above described ceases to flow, and the bark of the tree then adheres to the alburnum. Afterwards from the middle of June to the middle of August, as Dr. Bradley has observed, there seems to be a pause in vegetation; at which time the new buds in the bosom of each leaf seem to be generated, and the bark, which during the two preceding months adhered to the wood, now easily separates, as in the spring, according to the observation of Duhamel, Vol. II. 261; and vegetation, which appeared to languish during the heats of midsummer, acquires new vigour at the approach of autumn like that of spring.

This circumstance, which seems to have puzzled many naturalists, is to be explained from the action of the umbilical vessels of the new

buds, which begin to enlarge as soon as they are formed, and in this climate have their progress stopped by the cold during the winter, and the moisture which exsudes from the sides of these vessels, and is extravasated between the alburnum and the bark, causes an easy separation of them from each other.

From the new flow of sap in these vessels about midsummer, being probably in part conveyed to the leaves by the retrograde action of their lymphatics in very hot weather, the honey-dew seems to originate either as an exsudation from the leaf, or from the vessels being punctured by the aphid, which drinks the vegetable chyle in such great quantity that it passes through the insect almost unchanged; see Sect. XIV. 1. 7. and 3. 2; and thus causes the suffusion of honey on the leaves below them for a time in the heat of summer.

Add to this that M. Du Hamel, by nicely measuring some buds, found that they were gradually enlarged at some times during the winter, and concludes from thence that the sap-juice, which nourishes them, continues to flow, though slowly, in the milder parts of the winter days, Vol. II. p. 262; and adds, that it must rise continually during the winter months in ever-green trees, otherwise their foliage would wither; and also in deciduous trees, because the branch of an ever-green tree will grow on a deciduous tree, and not lose its leaves in the winter, as the *lauro-cerasus* on a cherry-tree, and an ever-green oak on a common oak.

It must nevertheless be observed, that as the umbilical vessels are a part of the new bud, as the lacteals and other absorbents are a part of the chick or fetus, the perpetual action of these umbilical vessels must depend on the bud to which they belong, in the caudex of which, between the plumula and radicle, the brain or common sensorium, and the consequent vital energy, are believed to reside; and that whether an ingraftment exists between the bud and the umbilical absorbent vessels or not. But as in those animals which have a very
small

small portion of brain in the head compared with that in the spine of the back, as in eels, snakes, worms, butterflies, if the head be cut off, the other parts will continue to live with great activity for hours, and even days; so it happens to these umbilical absorbent vessels, which in vine-stumps, and many herbaceous plants, will continue to pour out the sap-juice in great force and great quantity for many days after the excision of the whole upper part of the plant.

The continuance of the motion of these umbilical vessels consisting of a spiral line, which are believed to be air-vessels by many authors, is mentioned by Malpighi; who asserts, that when he examined them in the winter, he could often observe them for some time to continue their vermicular motion so as to astonish him. See Duhamel. *Phys. des arb.* Vol. I. p. 43.

9. The umbilical vessels of this section, like the absorbents of the preceding one, both which are believed to consist of a spiral line, as shewn in Sect. II. 7. may be readily seen in cutting a vine-stalk horizontally, as they at first appear full of fluid; but in a very little time, as the fluid exhales or becomes effused, a circular area of round holes appears to pass longitudinally interior in respect to the bark; which I suppose to consist both of the umbilical vessels, which bleed during the vernal months, and of the other radical, cellular, and cutaneous absorbents; the latter of which I suspect to be exterior to the former, and to reside between the bark and the umbilical vessels, though both of them are believed to constitute the alburnum of the plant.

From many ingenious observations on vegetables monsieur de la Baïsse draws the following conclusions, which are assented to by M. Bonnet, and which I shall here transcribe, as they so accurately coincide with the theory above delivered, and as they were deduced from different experiments, are a confirmation of it. He says, “ that the vessels destined to convey nourishment to plants are neither in the pith, nor in the bark, nor between the bark and the wood;

but

but in the ligneous substance itself; or, to speak more accurately, that those vessels are themselves the woody fibres included between the pith and the bark of plants, which have their origin in the roots, and extend themselves to every part of the plant." Bonnet usage des feuilles, p. 275.

PLATE III.

PLATE III.

Is copied from Malpighi Appendix de ovo Incubato, Tom. II. Fig. 54, and represents the chick in the egg on the fourteenth day of incubation. The chick rolled up swims in the amnios *aa*, which is kept moist by very minute vessels. Round this is placed the yolk *bb*, to which adjoins the thicker part of the white. The whole is surrounded with chorion *ddd*. On this are spread the blood-vessels, of which the large one *e* emerging from the navel of the chick, and generating the various branches *fff*, terminates in a capillary network. In contact with these a redder set of vessels passes with similar ramifications. Another set of vessels *gg* arises from the navel, which are smaller ones, and are propagated amidst the ramification of *ff*. The lungs are white; the stomach full of milk, or of coagulated albumen or white; and the intestines hang out from the navel.

As two sets of blood-vessels terminate on the chorion, and as one branch of the larger set carries redder blood, and as the lungs are still white; it seems evident, that this larger set of vessels resemble the placental arteries and vein of viviparous animals, and that the blood receives its red colour by acquiring oxygen from the air included between the external moist membrane and the shell of the egg; which air at first is seen only at the broad end, but afterwards extends from thence to the equator of the egg, and probably passes through the other end of the shell to that part of the internal membrane, which adheres to it. See an analogous plate in Fabricius ab Aquapendente, Tom. I. Fig. 13. See also Sect. III. 1. 4. and III. 2. 6. of this work.



S E C T. IV.

THE PULMONARY ARTERIES AND VEINS OF VEGETABLES.

- I. 1. Leaves not perspiratory organs, nor excretory nor nutritious organs, nor electric nor luminous ones. 2. Vital air in the atmosphere, in water. Lungs of aërial animals; gills of aquatic ones. 3. Leaves are the lungs of vegetables. Arteries and veins visible in a leaf of spurge and picris coloured by madder, and in bloody dock. 4. Upper surface only of the leaf respire, and repels moisture, and dies if smeared with oil, and exhales much less than the under one. II. 1. Aquatic leaves are like the gills of fish; have larger surfaces, as the uncombined oxygen in water is less than in air; are divided like the leaves on high mountains. 2. Are furnished with numerous points like gills of fish. 3. Which set at liberty oxygen from some waters. III. 1. Root-leaves of many plants differ from stem-leaves. 2. As they produce only buds. 3. They differ as common leaves from floral leaves. 4. And arise sometimes from the cotyledons. IV. 1. Floral leaves or bractes are respiratory organs to the calyx and pericarp. 2. In some plants they do not appear till the corol drops off. 3. Recapitulation. Leaves die in the exhausted receiver. V. 1. The corol is a pulmonary organ; its colours. 2. Its vascular texture, its glands. Some flowers have no bractes. The corol is not for defence. The corol of helleborus niger changes to a calyx. 3. Corol of colchicum and crocus fall off before the bractes appear. Vines bear alternate flowers and leaves. Fruit deprived of green leaves. 4. Vegetable uterus requires the bractes. Flowers enlarged by destroying the green leaves. 5. Plants do not respire in their sleep. 6. Conclusion. The anthers and stigmas are separate vegetable beings; live on honey and acquire greater irritability, and amatorial sensibility.

I. 1. THERE have been various opinions concerning the use of the leaves of plants in the vegetable economy. Some have contended, that they are perspiratory organs. This does not appear probable from an experiment of Dr. Hales, Veg. Stat. p. 30. He found, by cutting off branches

branches of trees with apples on them, and taking off the leaves, that an apple exhaled about as much as two leaves, the surfaces of which were nearly equal to that of the apple ; whence it would appear, that apples have as good a claim to be termed perspiratory organs as leaves.

Others have believed them the excretory organs of excrementitious juices ; but as the vapour exhaled from vegetables has no taste, this idea is no more probable than the other. Add to this, that in moist weather they do not appear to perspire or exhale at all, as shewn by some statical experiments of Dr. Hales, like those of Sanctorius on the perspiration of the human body ; which perspiration has also been supposed to be an excrement, which is shewn to be an erroneous opinion ; and that its design is simply to preserve the skin supple, like the tears diffused on the eye-ball to preserve its transparency, as explained in *Zoonomia*, Vol. II. Class I. 1, 2. 14.

Others have believed that vegetables absorb much nutriment by their leaves, and quote an experiment of Dr. Priestley's, who found plants placed in water under glasses grew much faster, when the air, in which they grew, was occasionally impregnated with putrid exhalations. But there is another experiment of Dr. Priestley's, which should be mentioned, and that is, that he agitated one part of a vessel of water beneath a glass filled with putrid exhalation, and the whole of the water presently became very fetid. Hence we may conclude, that in the first case the water, in which the vegetable grew, absorbed the putrid exhalations from the air over it, and that these were again absorbed from the water by the roots of vegetables, which correspond to the lacteals of the stomach and intestines of animals ; and that they thus received nourishment from the putrid vapours, and not by their leaves, which we shall endeavour to shew to be simply respiratory organs.

Other philosophers have conceived, that the leaves of plants acquire electricity from the air. In answer to these it may be observed, that

no electricity is shewn by experiments to descend through the stems of trees, except in thunder storms; and that if the final cause of vegetable leaves had been to conduct electricity from the air, they ought to have been gilded leaves with metallic stems.

Others again have supposed that the leaves of plants acquire a phlogistic material from the sun's light, whence it was believed that on this account they turn their upper surfaces to the sun. But though light is more or less attracted by all opaque bodies, yet if the final cause of vegetable leaves had been to absorb light, they ought to have been black and not green; as by Dr. Franklin's experiment, who laid shreds of various colours on snow in the sun-shine, the black sunk much deeper than any other colour, and consequently absorbed much more light. The use of light in vegetable respiration will be treated of in Sect. XIII.

2. The air of our atmosphere has been shewn by the experiments of Priestley, Cavendish, and Lavoisier, to consist of twenty-seven parts of respirable air, called oxygene gas, with seventy-three parts of unrespirable air, termed azotic gas, which are mixed together, not chemically combined; whereas water consists of eighty-five hundredth parts of oxygen to fifteen of hydrogen, which exist in their state of combination, and are not therefore fit for respiration. But in water a considerable quantity of common air is also dissolved, which escapes on boiling; and even pure vital air was discovered in the water of some springs by sir Benj. Thomson, when it was exposed to the sun's light. Philosoph. Transact. The former of these fluids is thus adapted to the respiration of aerial animals, and the latter to that of aquatic ones; and the analogy between the aerial and aquatic leaves of vegetables and the lungs and gills of animals embraces so many circumstances, that we can scarcely withhold our assent to their performing similar offices.

The internal surface of the air-vessels of the lungs of men are said to be equal to the external surface of the whole body, or about fif-

teen square feet. On this surface the blood is exposed to the influence of the respired air, through the medium of a thin moist pellicle. By this exposure to the air it has its colour changed from deep red to bright scarlet, and acquires something so necessary to the existence of life, that we can live scarcely a minute without this wonderful process.

In aquatic animals, as fish, the blood is exposed to the air, which is diffused in the water by the gills; the surface of which is probably greater in proportion to the external surface of their bodies, than that of the air-vessels of the lungs of aerial animals to their external surfaces. Through these gills, or aquatic lungs, a current of water is made perpetually to pass by the gaping of the fish, as it moves, like the air in respiration; and from this water it is probable the same material is acquired by the gills of fish as from the air by the lungs of aerial animals.

3. The great surface of the leaves compared to that of the trunk and branches of trees is such, that it would seem to be an organ well adapted for the purpose of exposing the vegetable juices to the influence of the air. This however we shall see afterwards is probably performed only by their upper surfaces, which are exposed to the light as well as air, and on that account acquire greater oxygenation, as will be shewn hereafter: yet even in this case the upper surfaces of the leaves must bear a greater proportion to the surface of the bark of the tree than that of the air-cells of the lungs of animals to their external surfaces.

Aerial or aquatic animals, by their muscular exertions, produce a current of air or water reciprocally to and from their lungs, and can occasionally change the place, where they respire, when the air or water becomes vitiated. But as vegetables have but little muscular power to move their leaves, except in a few instances; and as the air or water is frequently nearly stationary, where they exist, it seems to have been necessary to expose their fluids to the air or water on a
greater

greater expanse of surface than in the lungs or gills of animals, which well accounts for the exuberant extent of their foliage.

In the lungs of animals the blood, after having been exposed to the air in the extremities of the pulmonary artery, is changed in colour from deep red to bright scarlet, and is then collected and returned by the pulmonary vein. So in the leaves of plants the vegetable blood is rendered yellow in some plants, as in celandine, chelidonium; white in others, as in fig-leaves, ficus; and in spurge, euphorbia; and red in others, as in red beets, beta. And the structure of the leaf, as consisting of arteries and veins to expose the vegetable blood to the influence of the air, and to return it to the caudex of the bud at the foot-stalk of the leaf, beautifully became visible by the following experiment.

A stalk with the leaves and feed-vessels of large spurge (*euphorbia helioscopia*) in June 1791, had been several days placed in a decoction of madder, (*rubia tinctoria*) so that the lower part of the stem and two of the inferior leaves were immersed in it. After having washed the immersed leaves in much clean water, I could readily discern the colour of the madder passing along the middle rib of each leaf. This red artery was beautifully visible both in the under and upper surface of the leaf; but on the upper side many red branches were seen going from it to the extremities of the leaf, which on the other side were not visible except by looking through it against the light. On this under side a system of branching vessels carrying a pale milky fluid, were seen coming from the extremities of the leaf, and covering the whole underside of it, and joining into two large veins, one on each side of the red artery in the middle rib of the leaf, and along with it descending to the foot-stalk or petiole. On flitting one of these leaves with scissors, and having a common magnifying lens ready, the milky blood was seen oozing out of the returning vein on each side of the red artery in the middle rib, but none of the red fluid from the artery.

All these appearances were more easily seen in a leaf of *picris* treated in the same manner; for in this milky plant the stems and middle-rib of the leaves are sometimes naturally coloured reddish, and hence the colour of the madder seemed to pass further into the ramifications of their leaf-arteries, and was there beautifully visible with the returning branches of milky veins on each side.

In a plant which was sent to me under the name of *senecio bicolor*, but which I have not yet seen in flower, the upper surface of the leaf is green like most other leaves, but during the vernal months the under surface is of a deep red, whence I conclude that the vegetable blood acquires the red colour in the terminations of the pulmonary artery in the upper surfaces of the leaves, which becomes visible as it passes in the large veins on the inferior surface. In the same manner the red colour of the blood is most visible in the large veins beneath the leaf of the red veined dock, *rumex sanguinea*.

4. From these experiments the upper surface of the leaf appeared to be the immediate organ of respiration, because the coloured fluid was carried to the extremities of the leaf by vessels most conspicuous on the upper surface, and there changed into a milky fluid, which is the blood of the plant, and then returned by concomitant veins on the under surface, which were seen to ooze when divided with scissars, and which in *picris* particularly rendered the under surface of the leaves greatly whiter than the upper one.

As the upper surface of leaves constitutes the organ of respiration, on which the vegetable blood is exposed in the terminations of arteries beneath a thin moist pellicle to the action of the atmosphere, these surfaces in many plants strongly repel moisture, as cabbage-leaves, whence the particles of rain lying over their surfaces without touching them, as observed by Mr. Melville, (*Essays Literary and Philos. Edinb.*) have the appearance of globules of quick-silver. And hence leaves laid with their upper surfaces on water wither as soon as in the dry air, but continue green many days if placed with their under surfaces on water,

water, as appears in the experiment of monsieur Bonnet, (*Usage des Fevilles*) ; hence some aquatic plants, as the water-lily (*nymphæa*) have the lower sides of their leaves floating on the water, while the upper surfaces remain dry in the air.

This repulsion of the upper surfaces of the leaves of aerial plants to water bears some analogy to the renitency of the larynx to the admission of water into the lungs of animals ; for if a single drop accidentally falls into the windpipe, a convulsive cough is induced till it is regurgitated. For the same reason several plants close together the upper surfaces of their leaves when it rains, in the same manner as in their sleep during the night, as *mimosa*, the sensitive plant, and the young shoots of chick-weed, *alfine* ; and of kidney-bean, *phaseolus*.

As those insects which have many spiracula, or breathing apertures, as wasps and flies, are immediately suffocated by pouring oil upon them, in the year 1783 I carefully covered with oil the surfaces of several leaves of *phlomis*, of Portugal laurel, and balsams ; and though it would not regularly adhere, I found them all die in a day or two, which shews another similitude between the lungs of animals and the leaves of vegetables.

There is an ingenious experiment of M. Bonnet, (*Usage des feuilles*) which shews that the upper surfaces of leaves exhale much less than their under surfaces. He put the stalks of many leaves fresh plucked from trees or herbaceous plants into glass tubes filled with water ; of these he covered with oil or varnish the upper surface of many leaves, and the under surface of many others, and uniformly observed by the water sinking in the tubes that the upper surfaces exhaled much less than half the quantity exhaled by the under surfaces, which shews them to be organs designed for different purposes.

II. 1. There exists a strict analogy between the leaves of aquatic plants, which are constantly immersed beneath the water, and the gills of
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of aquatic animals, which consists in the largeness of their surface, owing to their hair-like subdivisions, and to their being terminated with innumerable points. The gills of fish consist of many folds of blood-vessels lying over each other, each resembling a fringe, or the downy part on one side of a feather attached to the middle rib of it, by which means they expose a greater surface of blood to the water than is exposed to the air by the internal membranes of the air-cells of the lungs of other animals; and undoubtedly for this final cause, because water contains less oxygen in its uncombined state, which is the material necessary to life, than air, though much more of it in its combined state, as water consists of eighty-five parts of oxygen to fifteen parts of hydrogen; but it is the uncombined oxygen only dissolved in heat, and diffused in water, which can serve the purpose of animal or vegetable respiration.

The apparatus for this purpose, according to Duverney's Anatomy of a Carp, is truly curious. He found 4386 bones in the gills, which had sixty-nine muscles to give them their due motions. See Boreau's Dictionnaire raisonné, Art Poisson. And Monro observed by the numerous divisions and folds of the membrane of the gills, that their surface in a large skate was nearly equal to the surface of the human body. *Physiol. of Fish*, p. 15. He adds that in the whole gills there exist 144,000 subdivisions or folds, and that the whole extent of this membrane may be seen by a microscope to be covered with a network of exceedingly minute vessels.

2. In this respect the gills of fish are resembled by the subaquatic leaves of plants, which are slit into long wires terminated in points, as in *trapa*, *œnanthe*, *hottonia*, the water-violet, and the water-ranunculus. This last plant, and some others, have frequently some leaves erect in the air, and others immersed in water, arising from the same stem; and it is curious to observe that the aerial leaves are nearly entire, or divided only into a few lobes; whilst the aquatic leaves are slit into innumerable branches like a fringe, and have thus

their surfaces wonderfully enlarged for the purpose of acquiring uncombined oxygen from the air, which is diffused in the water, and which abounds so much less there than in the atmosphere; for the same purpose the plants on the summits of high mountains, where the air is so much rarer, and consequently abounds less with oxygen, have their leaves much more divided than in the plains, as *pimpinella*, *petroselinum*, and others, that they may expose a more extensive surface of vessels to the influence of the thinner atmosphere.

3. This great enlargement of the surface by so minute a division does not however seem to be the only use of this uniform structure of gills and aquatic leaves; but there is another very important one, which hath hitherto I believe escaped the notice of philosophers; and that is that points and edges contribute much to the separation of the air, which is mechanically mixed or chemically dissolved in water, as appears on immersing a dry hairy leaf into water fresh from a pump, on which innumerable globules of air, like quick-silver, appear on almost every point. Nor is it improbable that points immersed in water may in a bright day contribute to decompose it, or certainly to set at liberty its superabundant oxygene, as occurs in the perspiration of leaves when exposed to the sunshine, and to the green matter in the experiments of Dr. Priestley, which is probably owing to the fine points of both of them; and lastly, when points of silk are immersed in spring water, which is frequently hyperoxygenated, as in the experiments of Count Rumford, related in the *Philos. Transact.* See Sect. XIII. I. 5.

III. 1. The *root-leaves* of many perennial plants, which do not produce flowers in the first year from the seed, are different from those of future years, as in the *rheum palmatum*, palmated rhubarb, the leaves are small and nearly circular, and not divided into fingers till the second year; and in tulip the leaf the first year from the seed is small like a blade of grass, rising from a diminutive bulb. In other perennial plants the *root-leaf* is undivided, but at the same time larger than

than those on the rising stem, as in geum, avernus; in fenecio aureus, and the campanula rotundifolia, so named from the round form of the root-leaf, which is also much broader than those on the stem, as well as undivided. The root-leaves of many biennial, and of some annual plants, are likewise larger, as well as of a different form from those on the rising flower-stem, as in turneps and carrots. And lastly, the root-leaves of some plants, which rise immediately from seeds, consist of the cotyledons of the seed, and are thus different from the leaves above them.

2. In respect to the root-leaves of palmated rhubarb and of tulips, when these plants are raised immediately from seed, as these first plants are not designed to generate flowers and consequent seeds, but to produce simply another plant like a leaf-bud of a tree, less oxygenation seems to have been necessary, and the leaves therefore require less surface, and are in consequence undivided. In respect to the root-leaves of geum, and of campanula rotundifolia, which are larger than their stem-leaves, it is probable that they lay up a reservoir of nutritious matter for the rising stem, like those of turneps and carrots, and thus require greater oxygenation, and in consequence a greater surface.

3. Another difference of root-leaves from those of the stem in annual plants often consists in the latter being properly bractes or floral-leaves, which will be spoken of below, while the root-leaf resembles those belonging to the leaf-buds of trees. Thus in the rising stem of wheat the root-leaf produces the first joint above the soil, and the second and third leaf produce joint above joint, which are each a separate bud rising on that below it, as is seen by the division of the pith or hollow part of one joint from another, and at length the uppermost leaf is a bracte or floral-leaf belonging to the ear.

4. And lastly, the seed-leaves which rise out of the ground with the first joint of the flower-stem, as in kidney-bean, phaseolus, as they consist of the placental artery, which was spread on the cotyledons

dons of the seed, and, now rising out of the earth, when the nutritive part has been dissolved in the terrein moisture and absorbed, they serve the office of an aerial pulmonary organ, or lungs, which before served that of an aquatic one, or gills; but wither and fall off as the true leaves become expanded.

IV. 1. The common foliage of deciduous plants constitutes the organ of respiration already spoken of, which belongs to the leaf-buds during the summer months, and drops off in the autumn, when those buds perish by the cold, or by the natural termination of their existence. But there is another kind of foliage dissimilar to the former, consisting of bractes or floral-leaves, which supply an organ of respiration to the calyx and pericarp of the flower-bud. These frequently differ in size, form, and colour from the other leaves of the plant, and are situated on the flower-stalk often so near the fructification as to be confounded with the calyx. In some plants there are two sets of floral-leaves, or bractes, one at the foot of the umbel, and another beneath each distinct floret of it; and in others they appear in a tuft above the flower, as well as on the stalk beneath it, as in *fritillaria imperialis*, crown imperial; and in others they are so small as to be termed *stipulæ* or props.

All these kinds of bractes, or floral-leaves, serve the office of lungs for the purpose of exposing the vegetable blood to the influence of the air, and of preparing it for the secretion, or production and nourishment of the vegetable uterus, or pericarp, and of the seeds produced and retained in it, frequently before their impregnation, and always after it.

2. It must be observed that in many plants these floral-leaves, or bractes, do not appear till after the corol and nectaries, with the anthers and stigmas, drop off; that is, not till after the seed is impregnated, as in *colchicum autumnale*, *crocus*, *hamamelis*, and in some fruit-trees. The production of the vegetable uterus, or pericarp, with the unimpregnated seeds included in it, is in these plants accomplished or

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evolved,

evolved, like the bractes themselves with the corol and sexual organs, by the sap-juice, forced up in the umbilical vessels from some previously prepared reservoir, without the necessity of any exposition to the air in leaves or lungs, which are not yet formed, though it may acquire oxygenation in the fine arteries of the embryo buds, which are supposed to surround the horizontal air-vessels observed in the bark of trees.

As soon as the seeds become impregnated, the corol and nectaries with the sexual organs fall off, and the pericarp and its contained seeds are then nourished by the blood, which is aerated or oxygenated in the bractes, or floral-leaves. Thus the flower of the colchicum appears in autumn without any green leaves, and the pericarp with its impregnated seeds rises out of the ground in the ensuing spring on a stem surrounded with bractes, and with other green leaves below them, which produce new bulbs in their bosoms.

The blood, which thus supplies nutriment to the pericarp and its included seeds, does not seem to require so much oxygenation as that which supplies nutriment to the embryo buds; whence the floral leaves are in general much less than the root-leaves in many plants, and than the common green leaves of almost all vegetables. And in the plant mentioned in No. I. 3. of this section, under the name of *fenecio bicolor*, the under surfaces of the stem-leaves near the expected flower ceased to be red like those of the radical leaves, which seemed to shew that the vegetable blood was in them less oxygenated.

Whence it may be believed that less irritability may be necessary for the growth of the seed than of the embryo bud, as the former does not yet perhaps possess so much vegetable life as the latter. And lastly, that as the anthers and stigma require greater irritability, and some sensibility, it was necessary a second time to oxygenate the blood which supplies them with nutriment in the corols of the flowers. See Sect. VII. 2. 4.

3. Recapitulation of the arguments tending to shew that the leaves
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of vegetables are their lungs. 1. They consist of an artery, which carries the sap to the extreme surface of the upper side of the leaf, and there exposes it under a thin moist pellicle to the action of the air; and of veins, which there collect and return it to the foot-stalk of the leaf, like the pulmonary system of animals. 2. In this organ the pellucid sap is changed to a coloured blood, like the chyle in passing through the lungs of animals. 3. The leaves of aquatic plants are furnished with a larger surface, and with points like the gills of aquatic animals. 4. The upper sides of aerial leaves repel moisture, like the larynx of animals. 5. Leaves are killed by smearing them with oil, which in the same manner destroys insects by stopping their spiracula, or the air-holes to their lungs. 6. Leaves have muscles appropriated to turn them to the light, which is necessary to their respiration, as will be shewn in the Section on Light. 7. To this may be added an experiment of Mr. Papin related by M. Duhamel. He put an intire plant into the exhausted receiver of an air-pump, and it soon perished; but on keeping the whole plant in this vacuum except the leaves, which were exposed to the air, it continued to live a long time, which he adds is a proof that the leaves are the organs of respiration. *Physic des arbres*, V. I. p. 169.

V. 1. The organs of respiration already described consist of the green leaves belonging to leaf-buds, and of the bractes belonging to flower-buds. But there is another pulmonary system totally independent of the green foliage, which belongs to the sexual or amatorial parts of the fructification only, I mean the corol or petals. In this there is an artery belonging to each petal, which conveys the vegetable blood to its extremities, exposing it to the light and air under a delicate moist membrane covering the internal surface of the petal, where it often changes its colour, as is beautifully seen in some party-coloured poppies, though it is probable that some of the iridescent colours of flowers may be owing to the different degrees of tenuity

of the exterior membrane of the petal refracting the light like soap-bubbles.

The vegetable blood is then collected at the extremities of the corol-arteries, and returned by correspondent veins exactly as in the green foliage, for the sustenance of the anthers and stigmas, and for the important secretions of honey, wax, essential oil, and the prolific dust of the anthers, and thus constitutes a pulmonary organ, as is shewn by the following analogies.

2. First, the vascular structure of the corol, as above described, and which is visible to the naked eye; and its exposing the vegetable juices to the air and light during the day evinces that it is a pulmonary organ.

Secondly, as the glands which produce the prolific dust of the anthers, the honey, wax, and frequently some odiferous essential oil, are generally attached to the corol, and always fall off and perish with it, it is evident that the blood is elaborated or oxygenated in this pulmonary system for the purpose of these important secretions.

Thirdly, many flowers, as the colchicum and hamamelis, arise naked in autumn, no green leaves appearing till the ensuing spring; and many others put forth their flowers, and complete their impregnation early in the spring, before the green foliage or bractes appear, as mezereon, and some fruit-trees, which shews that these corols are the lungs belonging to these parts of the fructification.

Fourthly, this organ does not seem to have been necessary for the defence of the stamens and pistils, since the calyx of many flowers, as tragopogon, performs this office; and in many flowers these petals themselves are so tender as to require being shut up in the calyx during the night. For what other use then can such an apparatus of vessels be designed?

Fifthly, in the helleborus niger, Christmas-rose, after the seeds are grown to a certain size, the nectaries, and stamens, and stigmas, drop off,

off, and the beautiful large white petals change their colour to a deep green, and gradually thus become a calyx, inclosing and defending the ripening seeds; hence it would seem that the white vessels of the corol served the office of exposing the blood to the action of the air, for the purposes of separating or producing the honey, wax, and prolific dust; and when these were no longer wanted, that these vessels coalesced, like the umbilical vessels of animals after their birth, and thus ceased to perform that office, and lost at the same time their white colour. Why should they lose their white colour unless they at the same time lost some other property besides that of defending the seed-vessel, which they still continue to defend?

Sixthly, neither the common green leaves nor the bractes are necessary to the progress of the corol, and stamens, and stigma, or to the secretion of honey, after the last year's leaves are fallen off, as is evinced by the flowers of colchicum in the autumn, and of crocus in the spring, in both which the seeds rise out of the earth with their common leaves and bractes so long after the disappearance of the flower. In deciduous plants the common green leaves serve as lungs in the summer and autumn to each individual bud, which then produces the new buds in its bosom, which are either leaf-buds or flower-buds. In the ensuing spring the new common leaves are the respiratory organ belonging to the leaf-buds, and the bractes are the respiratory organ to the pericarp, and its included seeds before or after impregnation; and the corols, as soon as expanded, become the lungs to the amatorial parts of the fructification, and require neither the green leaves nor bractes.

3. Hence the vine bears fruit at one joint without leaves, and leaves at the other joint without fruit. Hence the flower of the colchicum rises out of the ground without bractes or other green leaves, and flourishes till the seed is impregnated; and the bractes, which rise out of the ground on the stem in the following spring, are lungs to give maturity to the pericarp and seed; and the other green leaves are

for the purpose of producing new bulbs round the old one, but can have nothing to do with the corol, anthers, stigmas, and nectaries, which have long since fallen off, and perished. And lastly, when currant or gooseberry trees lose their common green leaves, and their bractes, by the depredation of insects; the new leaf-buds become small and weak, but the corol, anthers, stigmas, and nectaries, continue to flourish, and the fruit becomes impregnated, though it is less sweet and of less size from the pericarp and included seed wanting their due nutrition by the bractes before or after impregnation.

4. It hence appears that the flower-bud, after the corol, stamens, stigmas, and nectaries fall off, becomes simply a vegetable uterus, for the purpose of supplying the growing embryos with nourishment, and possesses a system of absorbent vessels, which brings the sap-juice to the foot-stalk of the fruit, and which there changes into a pulmonary artery, which constitutes the bractes or floral-leaves, and exposes the acquired juices to the oxygenation of the air, and converts them into vegetable blood. This blood is collected again by the veins of the bractes, and conveyed by an adapted or aortal artery for the various secretions of saccharine, farinaceous, or acescent materials, for the nourishment of its included embryos, or the construction of the fruit and seed-lobes.

At the same time, as perhaps all the vessels of trees inosculate, the fruit may become sweeter and larger when the green leaves as well as the bractes continue on the tree; but the corols with the stamens, stigmas, and nectaries, (the succeeding fruit not considered) suffer, I believe, no injury, when the green-leaves and even the bractes are taken off, as by the depredations of insects. Some florists have observed this circumstance, and affirm that in many plants when the leaves are pulled off, the flowers become stronger from their then producing no bulbs, as in tulips and hyacinths. The inosculation of vegetable vessels is evinced by the increased growth of one bud, when others in its vicinity are cut away.

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5. The sleep of plants has been much spoken of by Linneus and others, but there is a wonderful circumstance occurs in it, which has not been noticed ; which is, that it seems to resemble the torpor of winter-sleeping insects and other animals, as many plants do not appear to respire during this part of their existence ; for some vegetables close together the upper surfaces of their leaves, both during their sleep and in rainy weather, as mimosa, sensitive-plant ; phaseolus, kidney-bean ; and the terminal shoots of alsine, chickweed. Many other plants close their petals and calyxes during their sleep as well as in rain, as convolvulus ; and some even in the bright daylight, as tragapogon ; and yet all these plants are believed by gardeners to grow, when young, faster in the night.

We must observe, that this sleep of plants, though it may resemble the torpor of winter-sleeping animals, is not to be confounded with the state of deciduous plants in the winter, as that consists in the death of the last year's bud, and the embryo condition of the new buds. It would hence appear, that perpetual respiration is less necessary to the vegetable than to the animal world ; and that as less is wasted during the inactive state of sleep, it is possible that young plants may increase in weight, or grow faster, during this state of inactivity, as animals are observed to respire less frequently during their sleep, and yet are believed when young to grow faster during their hours of rest than of exercise. So both in the experiments of Dr. Hales and Dr. Walker on plants during the bleeding season, the ascent of the sap-juice not only stopped during the night, but sometimes became retrograde, which might nevertheless be ascribed to the torpor of the absorbent system induced by cold, as well as to that of sleep.

6. We may draw this general result, that the common leaves of trees are the lungs of the individual vegetable beings, which form during the summer new buds in their bosoms, whether leaf-buds or flower-buds, and which in respect to the deciduous trees of this climate

mate perish in autumn ; while the new buds remain to expand in the ensuing spring. Secondly, that the bractes, or floral-leaves, are the lungs of the pericarp or uterus, and to the growing feeds which it contains, as the bractes on the stem of the crown-imperial, *fritillaria imperialis*, and the tuft above its flowers. And thirdly, that the corol or petals are the lungs belonging to the anthers and stigmas, which are the sexual or amatorial parts of the plant, and to the nectaries for the secretion of honey, and to the other glands which affords essential oil and wax.

Lastly, the stamina and stigma with the petals and nectary, which constitute the vegetable males, and the amatorial part of the female, as they in some plants appear before the green leaves or bractes, as in *colchicum* and *mezereon*, and in all plants fall off when the female uterus is impregnated, would appear to be distinct beings, totally different both from the leaf-buds, which produce a viviparous progeny ; and also from the bractes with the calyx and pericarp, which constitute the vegetable uterus.

They must at first receive nutriment from the vernal sap-juice, like the expanding foliage of the leaf-buds, or the bractes of the flower-buds. But when the corol becomes expanded, and constitutes a new pulmonary organ, the vegetable juices are exposed to the air in the extremities of its fine arteries beneath a moist pellicle for the purpose of greater oxygenation, and for the important secretion of honey ; and then the anthers and stigmas are supplied with this more nutritious food, which they absorb from its receptacle, the nectary, after it has there been exposed to the air, and are thus furnished with greater irritability, and with the necessary amatorial sensibility, and live like bees and butterflies on that nutritious fluid. See Sect. VII. II. 4.

S E C T. V.

THE AORTAL ARTERIES AND VEINS OF VEGETABLES.

1. *Aortal arteries in vegetables have correspondent veins. Shewn by experiment on picris, tragopogon, and euphorbia. Seen in the calyx of flowers. Circulation shewn by ingrafting striped-passion-flower, and jasmine, and hardier scions on cankered stems, from fruit-grafts on bad stocks degenerating.* 2. *Vegetable circulation performed without a heart, as in the aorta and liver of fish.* 3. *Force of the mouths of absorbents greater than that of the heart in producing circulation. Why there is no pulsation in the vena portarum. Circulation in the veins of animals produced by absorption. Very small resistance in the capillaries and glands. Wounds in trees strongly absorb fluids except in the bleeding season.* 4. *Vegetable vessels too minute to carry red blood, hence not easily injected with coloured fluids. Charcoal injected with quicksilver, or melted wax.* 5. *Recapitulation. Circulation performed by irritability of the vessels, and by the great power of absorption, and the action of the sides of vessels consisting of a spiral line.* 6. *Vessels unite at the lower and upper caudex gemmæ. Absorbents and umbilical vessels consist of a spiral line. Experiment by placing euphorbium first in a decoction of galls, and then in a solution of green vitriol. Junction of great vein, absorbent trunk, and pulmonary artery in the upper caudex gemmæ. Embryon bud seen in contact with the pith. Experiments with charcoal injected with white paint, suet, wax, and quicksilver.*

I. THE two principal arteries in animal bodies are the pulmonary artery and the aorta. The former receives the blood from the right cavity of the heart, and dispersing it round all the air-cells which terminate the bronchia, or air-pipes of the lungs, exposes it to the influence of the atmosphere through the thin moist membrane, which lines them. This we have shewn in Sect IV. I. 3. to be resembled in its office by the vegetable arteries, which carry their blood up the

foot-stalks of the leaves, and expose it on the upper surface of them to the influence of the air through a thin moist pellicle, where it changes its colour, and returns by correspondent veins like the blood of animals.

The aortal arteries of the more perfect animals receive the blood from the left cavity of the heart, after it has been exposed to the influence of the air in the lungs, and disperse it by numerous ramifications over the whole body for the purposes of secretion and nutrition. In less perfect animals the aorta itself has a pulsation, and carries forward the blood without the assistance of a heart, as may be seen in the back of a full-grown silk-worm by the naked eye, and very distinctly by the use of a common lens. After the blood has passed the various glands and capillaries, it is received by another system of vessels, the veins, which constitute a kind of reservoir for the quantity of blood, that remains unexpended by the secretions, excretions, nutrition, and growth of the animal; by these it is again carried to the right cavity of the heart, and again exposed in the lungs to the influence of the air.

In a similar manner the branching veins, which bring the blood from the leaves of plants, after it has been exposed to the influence of the air, unite at the foot-stalk of each leaf into more or fewer trunks, as may be seen in tearing off the foot-stalk of a leaf of a chesnut-tree from the stem; and there without the interposition of a heart, like the circulation in the aorta of fish, and that in the livers of red-blooded animals, these venous trunks take the office of arteries, and disperse the blood downwards along the bark to the roots, and to every other part of the vegetable system, performing the various purposes of secretion, excretion, and nutrition, as was shewn in the experiment of placing a fig-leaf in a decoction of madder, described in Sect. IV. 1. 3. of this work.

But as vegetables drink up their adapted nourishment perpetually from the moist earth, and in consequence must be supposed to take

up no more than their perpetual waste may require, I formerly believed, that this reservoir, or venous system, was not necessary in vegetables; and that therefore probably it did not exist. I was induced to adopt this idea from having observed in cutting asunder a stem of large spurge, *euphorbia helioscopia*; in which the rising sap could not be mistaken for the milky blood; that much more of the vegetable blood flowed from the upper part of the plant than from the lower part of it; and I therefore suspected, that there was no returning veins correspondent to the descending aortal arteries. But first this must necessarily occur from the veins returning from the root effusing their blood slower than the arteries of the upper part of the plant. And secondly, if there were no returning veins from the lower part of the plant, there ought to have been no effusion of blood from it. I have since observed on cutting asunder a large plant of *picris*, and also a large plant of *tragopogon scorzonera*, and instantly inspecting them with a common lens; that two concentric circles of vessels were visible, which oozed a milky juice; the internal circle of the upper division of the two plants, and the external one of the lower division, appeared to bleed more copiously, and in quicker streams, than the external circle of the upper division, and the internal one of the lower division; whence I concluded, that the vessels of the internal circles were arteries, and those of the external ones veins; and that the arteries of the upper part of the plant, which arise from the upper part of the caudex of each individual bud, were thus seen to pour out more blood, and in a quicker stream, than the veins of the lower part of the plant, as they return from the roots.

Add to this, that as the pulmonary arteries in the green leaves of plants, and in their petals, have correspondent veins visible to the eye; and that these are also seen in the calyxes of some flowers, which from their other evident uses can not be esteemed pulmonary organs: There is the strictest analogy to believe, that the aortal arteries of the bark of the trunk and roots have also their correspondent veins.

Nevertheless to evince that the vessels returning from the roots of plants, which oozed out a milky juice, were in reality not absorbent vessels, I cut off the stem of a large spurge plant, *euphorbia helioscopia*, about a foot and half from the ground, and bent it down into a cup of a decoction of madder, *rubia tinctoria*, in which it was confined two or three minutes; and wiping the end clean, I presently cut off about an eighth of an inch of it with a sharp penknife, and observed with a common lens the large absorbent vessels to be coloured with the madder, while the veins continued to effuse a little white blood; and thus demonstrated both the existence of absorbent vessels and returning veins. See Sect. II. 2.

At the same time the upper part of the plant had also its stem set in the decoction of madder, and after two or three minutes on cutting off about the eighth of an inch of it, or simply by wiping the extremity, the large absorbent vessels were seen by the naked eye to be coloured with the madder, and the arteries continued to effuse a large quantity of milky blood. The same experiments were tried on a plant of *tragopogon* with the same event.

It should be here observed, that the decoction of madder should be fresh made, as otherwise the colouring matter is liable to form itself into molecules, too large to be imbibed by any other vessels but the trunks of the absorbents, which may be said to resemble the receptaculum chyli of animals, as they pass from the lower extremity of the caudex of each bud to the upper one.

A proof of the circulation of the juices of plants has been deduced from the communication of white spots from a grafted scion to the whole of the tree in which it was ingrafted. Mr. Fairchild budded a passion-tree, whose leaves were spotted with yellow, into one which bears long fruit. The buds did not take, nevertheless in a fortnight yellow spots began to shew themselves about three feet above the inoculation; and in a short time afterwards yellow spots appeared on
a shoot,

a shoot, which came out of the ground from another part of the plant. Bradley on Gardening, Vol. II. p. 129.

And Mr. Lawrence observes, that the yellow striped jassamine has afforded a demonstration of the circulation of the juices in a tree; he inoculated in August the buds of striped jassamine-trees into the branches of plain ones; and asserts, that he has several times experienced, that if the bud lives but two or three months, it will communicate its virtue or disease to the whole circumfluent sap, and the tree will become entirely striped. Art of Gardening, p. 66. These are both of them important facts, as they are related from respectable authorities.

And I think I have myself observed in two pear-trees about twenty years old, whose branches were much injured by canker, that on ingrafting hardier pear-scions on their summits, they became healthier trees, which can only be explained from a better sanguification produced in the leaves of the new buds.

It has also been observed by an ingenious lady, that though fruit-trees ingrafted on various kinds of stocks are supposed to bear similar fruit, yet that this is not accurately so; as on some stocks she has known the ingrafted scions of apple-trees to suffer considerable change for the worse compared with the fruit of the parent-tree; whereas those scions, which can be made to grow by striking roots into the earth, she believes to suffer no deterioration. If this really occurs, it should be in a very slight degree, as the fruit is formed by the action of secretion, and depends on the glands of the part more than on any slight change of the vegetable blood, from which the secretion is selected or produced. Nevertheless if the fact be ascertained, it confirms the truth of the existence of a vegetable circulation.

2. The circulation of the vegetable juices in the leaves of plants, and in their trunks and roots, is performed without a heart, and is very similar to that in the aorta of fish. In fish the blood, after having passed through their gills, does not return to the heart, as from
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the lungs of air-breathing animals ; but the pulmonary vein, taking the structure of an artery, after having received the blood from the gills, which there gains a more florid colour, distributes it to the other parts of their bodies. A similar structure obtains in the livers of fish, as well as in those of air-breathing animals ; the blood is collected from the mesentery and intestines by the branches of their proper veins, which unite on their entrance into the liver, branch out again, and assume the office of an artery, under the name of *vena portarum*, distributing the blood through that large viscus for the purpose of the secretion of bile ; whence we see in these animals two circulations independent of the power of the heart. First, that which begins in the mesentery and intestines, and passes through the liver ; and secondly, that beginning at the termination of the veins of the gills, and passing through the other parts of the body ; both which circulations are carried on by the action of those respective arteries and veins. *Monro's Physiology of Fish*, p. 19.

The course of the fluids in the leaves, and in the trunks and roots of vegetables, is performed in a similar manner. First, the absorbent vessels of the roots, of the internal cells, and of the external bark, with the venous blood returning from those parts, unite at the foot-stalk of the leaf ; and then, like the *vena portarum*, an artery commences without the intervention of a heart, and receiving the sap and venous blood spreads it in numerous ramifications on the upper surface of the leaf ; here it changes its colour, and becomes vegetable blood ; and is again collected by a pulmonary vein, and returns on the under surface of the leaf. This vein, like that which receives the blood from the gills of fish, assumes the office of an artery, which corresponds with the aorta of animals, and branching again disperses the blood upward to the plumula or summit of the bud, from its caudex at the foot-stalk of the leaf, and downward along the bark of the trunk to the roots ; where it is received by a vein corresponding to the *vena cava* of animals, after having expended what was required for the secretions,

tions, excretions, and nutrition, and returns to the caudex of the bud, and to the foot-stalk of the leaf.

3. The power, which produces a circulation without a heart in vegetables, acts with an astonishing force. In some of the experiments of Dr. Hales, who fixed glass tubes to vine-stumps in the spring, the sap-juice rose above thirty feet; and in some trees must probably arise still higher in the vernal months before the leaves are expended; and this either solely by the activity of the absorbent mouths of these vessels, or assisted by the vermicular action of their sides, which appear to consist of a spiral line, as described in Sect. II. 7. of this work.

When the sap-juice rises thirty-five feet high, which is about the weight of the atmosphere, the column presses about fourteen pounds on every square inch. Now if the area of the mouth of an absorbent vessel be only one ten thousandth part of the area of a square inch, the ten thousandth part of fourteen pounds is the whole that counteracts the efforts of each absorbent mouth; and as the vessels of vegetables appear to have both very minute diameters, and very rigid sides, they are thence prevented from aneurism or rupture by the pressure of so high a column of sap-juice.

The same philosopher, by fixing glass tubes to the arteries of horses, as near the heart as was practicable, found the blood in them to rise only nine or ten feet; whence it appears, that a circulation of blood may be carried on more forcibly by the action of the mouths of absorbent vessels, than by the apparently more violent exertions of the heart, the power of which was calculated by Borelli and others to be so enormously great, as to equal the pressure of some thousand pounds, as the counter pressure of the moving blood acts on so large a surface as that of the whole internal sides of the heart.

But as a column of blood nine feet high presses with less than one third of the weight of the atmosphere, or about four pounds on every square inch of surface; and as the internal surface of the left cavity
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of the heart of a horse may not exceed thirty square inches, its whole power does not overcome the resistance of more than 120 pounds.

Hence it becomes intelligible, how the circulation of the blood in the vena portarum of the liver is performed without any apparent pulsation, or contraction of its sides like an artery, which some have indeed supposed it to possess, but simply by the force of absorption exerted by the mouths of the veins, which supply it with blood.

Secondly, how the circulation of the blood in the bodies of fish, except in their gills, is carried on through their system without the action of the heart. And thirdly, how the blood in the vena cava of the human body, as well as the fluids imbibed by the lacteals and lymphatics, are carried forwards to the heart by the power alone of their absorbent mouths, which drink up their blood from the capillaries, or their other fluids from the surfaces or cavities of the body. And lastly, how the whole circulation in vegetables is performed in very minute vessels without valves, and without a heart, solely by the power of absorption, circumstances which have long perplexed the physiology both of the animal and vegetable kingdoms.

Another circumstance attending the circulation of the juices in vegetables, as well as the circulation of the blood in animal bodies, has not been sufficiently attended to; and that is, that the resistance to the passage of these fluids from the terminations of the arteries, in what are termed capillaries, to the beginnings of the veins, and through the glands of various kinds, is much less than is generally imagined, as we see with what great force the mouths of both the vegetable and animal absorbents imbibe their fluids; and that the beginnings of the veins, and the mouths of the lacteals and lymphatics, and probably those belonging to every kind of gland, possess this great power of absorption. And that on this account, when wounds are made in trees in the summer months, when the umbilical sap-vessels of the root have ceased to act, such wounds powerfully absorb any fluid, whether salutary or poisonous, which is applied to them, which does

not occur during the bleeding season, as the sap-juice from the diseased vessels of the alburnum supplies a greater quantity of fluid than the other parts of the wound can imbibe.

4. The red particles of blood have been said by Lewenhock and others, who have inspected them in microscopes, to be of the same size in all creatures. Hence nature has formed no very small animals with a general circulation of warm red blood; the mouse and humming-bird are perhaps the least. When it was necessary to form the vessels much more minute, a diluter kind of yellow or milky blood, or one nearly transparent, constitutes the greatest part of the vital fluid, as in insects of various kinds, and in the white muscles of fish; whence arose a difficulty to the anatomist of visibly injecting these smaller series of vessels, as they are too minute to convey almost any coloured particles.

In the vegetable world the finer systems of their vessels have still greater tenuity, and hence evade our eyes and microscopes; and as their coats possess at the same time a greater rigidity, they are in general on that account also incapable of receiving coloured injections, which has rendered the anatomy of plants so much more difficult to investigate than that of animals, and must apologise for the imperfections of this part of the work, but affords no argument against the existence of a vegetable circulation.

It is probable that by immersing charcoal, nicely made by slow calcination, in quicksilver, or even in melted coloured wax, as it so greedily absorbs almost all fluids, when recently taken from the fire, or cooled without the contact of air, we might produce beautiful vegetable preparations, and give more accurate light into the anatomy of plants. But the column of quicksilver employed to push forwards the injection should not be too high, lest it should rupture the vessels it ought only to fill, as I suppose has sometimes happened in thus injecting the glands or capillaries of animal bodies.

5. Recapitulation. We may finally conclude, that the circulation

of vegetables is performed like that of animals by the irritability of their vessels to the stimulus of the fluids, which they absorb and protrude; that is, that the extremities of the branching veins of the leaves forcibly absorb the vegetable blood from the extremities of their arteries, which correspond with the pulmonary arteries of animals; and that it is thus pushed on to the foot-stalk of the leaf, where the veins unite, and branching out again take the office of an artery, like the aorta in fish, without perceptible pulsation. The blood in this artery is pushed forwards by that behind it, the motion of which was given by the power of absorption in the pulmonary vein, till it arrives at the extremities of these aortal branches, and is there again forcibly absorbed by the terminations of the correspondent veins, and again pushed forwards to the caudex gemmæ, and to the foot-stalk of the leaf, like the blood in the vena cava of animals.

A part of this blood is at the same time forcibly selected and absorbed by the various glands for the purposes of the necessary secretions, excretions, or nutrition; and the sap-juice or chyle and the water, which is acquired by the absorbent vessels, that correspond to the lacteal and lymphatic vessels of animals, is carried, as well as the remainder of the blood, to the foot-stalk of the leaf. Here these absorbent vessels are believed to push their contents into the veins correspondent to the vena cava of animals, and which now uniting without the intervention of a heart, assume the name and office of the pulmonary arteries; and branching out upon the leaf expose the returning blood and new sap-juice to the influence of the air. And finally, all this is accomplished by the power of absorption, as in the aortal arteries, and vena portarum, of fish, which is excited into action by the irritability of the mouths of these vessels to the stimulus of the fluids, which they absorb.

2d. A circulation of vegetable juices, in every respect similar to that in the common leaves above described, exists in the bractes or floral-leaves, except that the leaves of the leaf-bud prepare their juices for
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the production and nourishment of other buds in their bosoms; but these bractes, which are the lungs of the fructification, prepare their juices for the nourishment of the pericarp and its included seeds, but not for that of the corol with its anthers and stigmas, as these in many flowers exist before the production of the floral-leaves, as in *colchicum* and *hamamelis*.

3d. Another circulation of vegetable juices exists in the sexual parts of flowers, including the nectaries and corols. In the corols the vegetable blood is exposed to the influence of the air, and prepared for the secretion of honey, which is the food or support of the anthers and stigmas, as treated of in the section IV. V. 1. and in Section VII. 4. In these the progression and circulation of the fluids must be caused by the power of absorption, which we have shewn to be a greater force than that of the heart of animals.

4th. The progress of the fluids imbibed by vegetable lacteals from the earth, and by their lymphatics from the air, and from the surfaces of their internal cells, is evidently began and carried on by the power of absorption of their terminating mouths, and the annular contraction of their spiral fibres.

5th. And lastly, the wonderful force with which the sap-juice is drank up and protruded in the umbilical vessels, which expands and nourishes the buds of trees, and which forms the wires of strawberries above ground, and those of potatoes under ground, with the great variety of bulbs and root-scions, is to be ascribed to this single principle of absorption. Except that some of these long cylindric vessels are evidently composed of a spiral line, as mentioned in Sect. II. 7. and which may by the annular contraction of this spiral line carry the fluids they have absorbed with great force either in a forward or retrograde direction.

6. Finally I conclude, that the branching absorbents of the roots unite at the lower caudex of each bud, before it rises out of the earth,

and forms a large trunk, which passes up the alburnum of the tree to the upper caudex of the bud at the foot-stalk of the leaf, and may be compared to the receptaculum chyli of animals extended to so great a length; and that it there joins the great returning vein, which also is composed of the branching veins of the roots uniting at the lower caudex of the bud, and ascending terminates at the upper caudex of it, where it becomes again branched, and forms the pulmonary artery.

The aorta or great artery descends, I suppose, along with the great vein, or vena cava above mentioned; and branching in the roots below, and on all other parts of the individual leaf-bud, performs the offices of secretion and nutrition. The pulmonary arteries and veins belong to the leaf; the former exposes the blood to the atmosphere beneath a thin moist pellicle, whence it becomes oxygenated, and probably acquires some warmth, and phosphoric acid, and the spirit of vegetable life. The latter collects the aerated blood by its branches, and conveys it to the upper caudex of the bud, at the foot-stalk of the leaf, where it becomes the aorta or great artery above mentioned.

The sides of the long absorbent trunks, or receptacles of chyle, which rise from the lower caudex and terminate in the upper caudex of each bud, as well as the long trunks of the umbilical vessels described in Sect. III. evidently consist of a spiral line, as well as those trunks of absorbents, which imbibe aqueous fluids from the air, and a part of their perspirable matter on the surfaces of the leaves. But whether the pulmonary and aortal arteries or great veins consist of a similar structure is not yet ascertained.

I shall here relate the following experiments, which were made a few days ago, to confirm or confute the ideas above delivered.

Some stems of large spurge, euphorbia, were set upright in a decoction of oak-galls, and others in a solution of green vitriol. On the next day these were reciprocally removed from the one to the other, as by this management I supposed that the black molecules would
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be produced in the vessels of the plants, and would thence appear higher in those vessels than if the black molecules had been formed by a mixture of the two fluids previous to their absorption.

On cutting these horizontally slice after slice with a sharp knife, and inspecting them with a common lens, the milky blood was seen to ooze, as before described, from an external ring of the bark ; and an interior ring of coloured points was agreeably visible many inches up the stem ; but on slicing the stem from below up to the insertion of the leaves and buds in their bosoms, I persuaded myself that I could perceive the coloured absorbents of the stem enlarged at the part where each with the attendant vein changes into a pulmonary artery, and passes into the leaf, forming three or more of the ribs of it, and thus constituting the upper part of the caudex gemmæ.

Another circumstance was beautifully visible, which was, that the coloured cylinder of absorbent vessels had evidently separated to allow the new bud to apply its interior termination to the pith ; which probably, when it was secreted by the glands of the caudex of the parent bud, found in this situation a proper nidus, and due nutriment for its embryon state, as in the uterus of the female.

Some other kinds of experiments I directed with design to shew the part of the lower caudex of each bud, where the branching absorbents and veins of the root unite each into one trunk, before they ascend along the bole of the tree ; and also to shew, as in the above experiment, the upper caudex of each bud, where the veins are joined by the absorbents, and become the pulmonary arteries of each leaf, but did not succeed quite to my wish, though what I could observe seemed to confirm the above theory. I had not leisure to repeat the experiments with sufficient attention, but shall here in few words describe the manner of making them, hoping some one may be induced to prosecute them with success, and to inject vegetable vessels, as the anatomists do those of animals.

A part of a leaf-stalk, and the joint to which it adhered, with
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about half an inch of the stem above and below the joint, were cut off from some last year's twigs, and also the caudex of some herbageous plants. These were covered with sand in a crucible placed on the fire, till they were red hot, so that the vegetable joints were become charcoal. They were then taken out of the sand, and some immersed in melted suet, others in melted bees-wax, others in white paint, and one or two in an amalgama of quicksilver and zinc, which happened to be prepared for the purposes of electricity. When they were cold, on slicing them, some horizontally, and others vertically, I persuaded myself that the blood-vessels above mentioned, as well as the pulmonary vein and aortal artery, were visible in the two extremities of the long caudex of the bud, as well as the long trunks of the arteries, veins, and absorbents, which constitute the middle part of it.

S E C T. VI.

THE GLANDS AND SECRETIONS OF VEGETABLES.

- I. 1. Glands of vegetables. *Their vessels are too minute for coloured injections.* 2. *They possess appetency. Are stimulated by the passing blood.* II. 1. Mucilage in all vegetables. 2. *Is a part of their nutriment, and convertable into sugar.* III. 1. Starch not soluble in cold water. *Potatoe bread.* 2. *Starch produced from mucilage, whence old grain better than new. Alum coagulates mucilage. Use of it in bread. How distinguished in bread by the eye. Is salutary in London bread. Is used in making hair-powder.* 3. *Frost converts mucilage into starch; snow pancakes.* 4. *Starch from poisonous plants is wholesome, and may be obtained by elutriation in times of scarcity.* IV. 1. Oils may be separated from bitter or narcotic materials, as the latter adhere to the mucilage. V. 1. Sugar formed by animal digestion. 2. *By vegetable digestion. Sugar is nutritive, but may injure the teeth.* 3. *In many roots it is found ready prepared. May be separated from mucilage by vinous spirit.* 4. *Exists in fruit formed from austere acids by a vegetable process.* 5. *By heat; by bruising austere fruit; by drying malt. Sugar converted into starch as well as starch into sugar. Use of sugar to vegetables and animals.* VI. 1. Honey guarded from insects, and from rain. 2. *Is of great importance. Is exposed to the air. Is reabsorbed, and is nutritious.* 3. *Depredation of insects on honey is injurious to vegetation. So is the honey-dew on trees. Bees also collect farina from flowers.* 4. *Why the honey is exposed to the air. Is the food of the anthers and stigmas. Differs from sugar by greater oxygenation. Benevolent economy of nature.* VII. 1. Wax preserves the anther-dust from rain. *How wet seasons injure wheat.* 2. *Wax collected from cistus labdiniferus. Bees much injure flowers.* 3. *Wax from candleberry-myrtle, and from croton sebiferum. Preserves or nourishes the immature seeds.* 4. *Wax deposited on plants by insects in China. Gives consistence to oil.* VIII. 1. Turpentine and essential oils are inadmissible with water. *Moist parts of vegetables are soonest destroyed by frost. Evergreen trees contain most resin. Defends the buds of deciduous plants.* 2. *Origin of petroleum; jet, amber, fossil, coal.*

coal. 3. *Essential oils agreeable. Poisonous. Preserve wood from insects. Used in Africa to poison weapons and pools of water.* 4. *Some essential oils burst into flame with nitric acid. Produce a vapour round dictamnus fraxinella.* 5. *Elastic resin. Bird-lime. Resinous part of wheat-flower.* IX. 1. *Bitter, narcotic, acrid juices, for the defence of plants. Opium exists in the poppy-head, but not in the seed. So of hyoscyamus. Narcotic matter in walnut-busks not in the seed. Oil of bitter almonds tasteless.* 2. *Acrid, astringent, emetic, cathartic, and colouring matters. Many poisonous plants in all our hedge-bottoms.* 3. *All these are strongest in the hybernaculum or winter-lodge of plants. When oaks should be decorticated.* X. 1. *Acids in fruit and leaves of various kinds. Convertible into sugar. For the nutriment of seeds and buds. For the defence of the plants.*

I. 1. THE structure of the glands of animals has not been yet fully ascertained. They consist of vessels so minute as to exclude all coloured injections, except quicksilver; and the terminations of these vessels are so tender, that the necessary weight of the quicksilver is liable to break them, and thus misinform the observer, as mentioned in Sect. V. 4. Little more is therefore known of them than their effect, which is, that they secrete, that is separate or produce, some fluid from the blood; as bile, saliva, urine, milk.

The vessels of vegetables being still more minute, and more rigid, the structure of their glands is still further removed from our discovery. Their effects are however as evident as those of the glands of animals in the secretion or production of various fluids, which become solid, as their aqueous parts are absorbed or exhaled, as mucilage, starch, oil, sugar, honey, wax, turpentine, essential oils, aromatics, bitters, narcotics, acrids, acids, and a variety of other materials, which fill our barns and granaries, and crowd the shops of the druggist.

2. There can be no doubt from what has been already said of the circulation of vegetable juices, but that their various secretions must be effected in a similar manner to that in animal bodies, which is believed

believed to be performed by the mouth of each gland being irritated into action by the stimulus of the blood, which is brought to it, and that by a kind of appetite it drinks up a part of the blood, and converts it to the fluid, which it secretes, which then becomes more or less solid, as its aqueous parts are absorbed or exhaled.

II. 1. Mucilage is found in all parts of plants, as being an essential constituent of vegetable as of animal bodies; so when an extract is made by boiling plants in water, the mucilage makes the greatest part of this extract. The mucilage called gum arabic is obtained from *mimosa nilotica*, gum tragacanth exsudes from *astragalus tragacantha*, as a similar gum exsudes from our cherry and plumb-trees; sago is the pith of the *lycas circinalis*; and salep is the root of the orchis dried in an oven.

This mucilage seems to serve as nourishment to the plant; first, because it is found in all vegetable as well as animal materials, as they decompose in dunghills; secondly, because it forwards the growth of vegetables, when spread upon land; thirdly, because those trees, which bleed much gum, are weakened and frequently die; and lastly, because it is evidently laid up in the roots and seeds of various vegetables for the nourishment of the young plants. But in these it seems to undergo a change either in part chemical, or wholly by the digestive organs of the embryo plant, and is converted into sugar, as in the transmutation of barley into malt; and as appears from the sweet taste of onions and potatoes, when boiled after they have germinated; and as sugar abounds in the vernal sap-juice of trees in such quantity as to be capable of fermentation.

III. 1. Starch is another kind of mucilage, which differs from those above mentioned in its property of not dissolving in cold water, and can hence be easily separated from them. If eight pounds of good raw potatoes be grated by means of a bread-grater into cold water; and, after well agitating the mixture, the starch be suffered to subside; and this starch be then mixed with eight other pounds of

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boiled

boiled potatoes, as good bread may be made as from the best wheat flour; as is affirmed by Monf. Parmentier. From this it appears, that the quantity of starch in potatoes and in wheat produces the principal difference of their respective flours. See *Zoonomia*, P. III. Article I. 2. 3. 4.

2. There is reason to believe that the mucilage during the growth of the plant is converted into starch; and that this process continues in grain some time after it is carried into the barn or granary, which occasions old wheat to produce better flour for the baker; and old oats and old beans are universally believed to give more nourishment to horses. I shall here add a conjecture, that I suppose the use of alum in making bread consists in its coagulating the mucilage, and perhaps thus contributing to convert it into starch; for the bakers mix it principally with new wheat; and affirm, that it makes the flour of new wheat equal to old.

Where much alum is mixed with bread, it may be distinguished by the eye by a curious circumstance, which is, that where two loaves have stuck together in the oven, they break from each other with a much smoother surface, where they had adhered, than those loaves do which do not contain alum.

Add to this, that alum is also used by the London bakers for the purpose of clearing the river water, with which they are supplied, which is frequently muddy; and also for instantaneously destroying the volatile alkali, which is said to exist in some London wells owing to the vicinity of dunghills. These purposes it probably fulfils by coagulating the mucilage, which may occasionally be mixed with the water and support the mud in it; or by uniting with the calcareous earth, or with the volatile alkali which it may contain, and depositing the new-formed gypsum, or its own argillaceous base, the descent of which may carry down other impurities along with it, in the same manner as some muddy wines have been rendered fine, not by filtering them through sand, as then the mud retained on the surface

surface of the sand soon prevents the descent of the wine through it, but by passing clean sand in showers by means of a riddle through the wine. Alum is said to be used by the Chinese for the purpose of cleaning the water of some stagnant reservoirs; and when used in small quantity may in all these respects be rather salutary than injurious to the bread of London.

Alum is said also to be used in the manufactory of hair-powder, which should consist of starch without mucilage, that the hair may not be glued together by the perspirable matter of the head, or by an accidental shower. Whether it has the property of converting mucilage into starch might be easily ascertained by experiment, by washing in cold water alone one parcel of wheat flour, and washing a similar parcel in a solution of alum in water.

3. Another conjecture I shall introduce here is, that it is probable that the action of frost also may tend to coagulate mucilage, or convert it into starch; for in the colder parts of Britain it is said, that the corn never ripens till they have frosty nights; and I well remember many years ago having observed, that some book-binder's paste made by boiling wheat-flour and water, after it had been frozen, ceased to cohere on being pressed together, like the crumbs of some bread; and I have been told by some housewives that their pancakes become much lighter if snow be mixed with the flour instead of water. See Sect. XVI. 3. 2.

4. Now as starch is not soluble in cold water, the bitter and acrid particles of plants may be washed from it along with the mucilage; whence in times of scarcity this nourishing part of vegetables may be obtained by elutriation from poisonous plants; on this circumstance principally depends the wholesomeness of the bread made from the cassava, the acrid and poisonous particles being previously washed away along with the mucilage. Mons. Parmentier found the starch from the root of the white bryony to contain no acrimony, and to be a wholesome article of food.

IV. 1. Many feeds contain much oil mixed with their mucilage, or starch; as nuts, almonds, flax-feed, rape-feed. Some of these contain also a bitter or narcotic material, as bitter almonds, apricot kernels, acorns, horse-chestnuts; which, as it adheres to the mucilage, may be separated from the oil; as in expressing the oil from bitter almonds, which is as good as from sweet ones. And it is probable by grating to powder, and washing in cold water, the kernels of acorns, and horse-chestnuts; or simply by pressure, that a wholesome starch, or oil, might be procured. It is probable also that the roots of fern treated in this manner would afford good nourishment, as these are said to be eaten by the inhabitants of New Zealand, and have been used in this country in times of great scarcity. And that the roots of nymphæa, water-lily, might be thus made into wholesome bread, (which are said to have been eaten in Egypt by Herodotus) and the roots of many other water-plants, which might thus become articles of subaquatic agriculture, which is an art much wanted in this country. See Sect. XI. 2. 5. and XVII. 2. 3.

V. 1. The digestive power of animals seems to be principally exerted in converting their food into sugar; since the chyle of all animals resembles milk, which contains much sugar, and thence spontaneously runs into fermentation, which terminates in the production of acid, as in butter-milk. In Siberia the natives distil a spirituous and intoxicating liquor from milk thus fermented. Gmelin. In the diabetes there is reason to believe, that the chyle passes off into the bladder without being previously mixed with the blood; and there is a curious history of a patient in the infirmary at Stafford, who laboured under a diabetes, he eat and drank thrice as much as most moderate men, and from sixteen to eighteen ounces, and even twenty ounces of coarse sugar was extracted for some time daily from his urine. Zoonomia, Vol. I. Sect. XXIX. 4.

2. In like manner the digestive powers of the young vegetable, with the chemical agents of heat and moisture, convert the starch or
mucilage

mucilage of the root or seed into sugar for its own nourishment ; or they obtain sugar ready prepared for them from some roots, as the beet-root ; from many fruits, as grapes, pears, peaches ; from the milk of cocoa-nuts, and from the sap-juice of the sugar-maple, birch, and many other trees. And thus it appears probable, that sugar is the principal nutriment of both animal and vegetable beings. That it is the most nutritive part of vegetable substances is evinced by the well ascertained fact, that the slaves in Jamaica grow fat in the sugar-harvest, though they endure at that time much more labour.

Yet there is an idle notion propagated amongst the people that sugar is unwholesome ; it is indeed probable, that the most nourishing materials may be taken more easily to excess, but not that it is therefore in general unwholesome ; at the same time it is probable, that some fruits preserved in syrup, or sweet-meats, may contribute to destroy the teeth ; since, if the sugar should become in a state of decomposition, and the saccharine acid should abound, it will dissolve calcareous earth with greater avidity than any other acid.

3. In many plants sugar is found ready prepared, as above mentioned ; thus in the beet-root, the crystals of it may be discerned by a microscope ; and may be extracted from the mucilaginous matter of the root by dissolving it in rectified spirit of wine ; which will unite with sugar but not with mucilage. In the joints of grass and of corn it may be discovered by the taste. In the manna-ash, *fraxinus ornus*, the same saccharine matter is produced along with the essential salt of the plant, which is purgative ; and in the sugar-cane it abounds in such large quantity as to contribute much to the nourishment of mankind. And,—and what ?—Great God of Justice ! grant, that it may soon be cultivated only by the hands of freedom, and may thence give happiness to the labourer, as well as to the merchant and consumer.

4. Another source of sugar in vegetables is in the fruit, which in many plants changes from an austere acid to a saccharine acid, as in gooseberries,

gooseberries, apples, oranges. This change continues to proceed after the pears and apples, or oranges, are taken from the tree into our storehouses, but the fruit in this situation continues to ripen by a vegetable process, as it can not be said to be dead, because it does not yet undergo fermentation or putrefaction, or other chemical dissolution; and though its progress in ripening may be forwarded by warmth, yet it must still be ascribed to a vegetable process; as the plants themselves grow quicker when exposed to additional heat.

5. But there are other means of increasing or hastening the saccharine process in austere vegetable fruits, as by bruising them, or by baking them, both which must destroy the life of the fruit; thus when apples are bruised for the purpose of making cyder, they become sweeter even in the act of bruising them; and many pears change from an austere to a sweet juice simply by the heat of baking; and it is probable that malt acquires a great part, though not the whole of its saccharine matter, in the act of drying. This chemical production or increase of sugar in vegetable juices is worth being further inquired into; since if sugar could be made from its elements without the assistance of vegetation, such abundant food might be supplied as might tenfold increase the number of mankind!

It is a curious circumstance not yet sufficiently understood, that not only starch appears to be convertible into sugar by the vegetable process of digestion, as in the germination of farinaceous seeds; but that sugar is capable of being converted into starch, as appears in the ripening process of some pears, which first contain a sweet-juice, and afterwards become mealy.

The use of this saccharine matter of the fruit or sap-juice in the vegetable economy is for the purpose of supplying the young seed or bud with nourishment to enable it the better to strike its roots into the earth, and to elevate its leaves into the air, and thus by its
quicker

quicker growth to rival its neighbours in their contentions for air, and light, and moisture, which are necessary for its existence.

VI. 1. The production of honey is perhaps one of the most important vegetable secretions, except that of the prolific farina from the anthers; and of the favilla, or new embryo, in the axilla of the leaf. The glands for this purpose, or certainly the reservoirs, which contain the honey after it is secreted, are in many flowers visible to the naked eye; as in crown-imperial, *fritillaria imperialis*; in monkshood, *aconitum napellus*; hellebore, *ranunculus*. It is nevertheless probable, that this reservoir of honey is frequently placed at a distance from the gland, which secretes it, for the purpose of preserving it from insects and from rain, which is often effected both by a very complicated apparatus, and by an acrid or poisonous juice, as in the aconites and the hellebores above mentioned.

As the nectary, or honey-gland, always falls off along with the corol, and anthers, and stigmas; these appear to be parts or appendages to each other. The vegetable blood is exposed to the air in the corol, and thus is oxygenated or prepared for the secretion of this important fluid; which I suppose is again reabsorbed, and supplies nourishment to the anthers and stigmas. Some acrid juices, and odorous particles, are at the same time secreted from the blood thus oxygenated in the corol; which seem designed as one kind of defence against the depredations of insects on this important reservoir of honey.

2. The universality of the production of honey in the vegetable world, and the very complicated apparatus, which nature has constructed in many flowers, as well as the acrid or deleterious juices she has furnished those flowers with, as in the aconite, to protect this honey from rain, and from the depredations of insects, seem to imply, that this fluid is of very great importance in the vegetable economy; and also that it was necessary to expose it to the open air previous to its reabsorption into the vegetable vessels.

In the animal system the lacrymal gland separates its fluid into the open air for the purpose of moistening the eye ; of this fluid the part, which does not exhale, is absorbed by the puncta lacrymalia, and carried into the nostrils ; but, as this is not a nutritive fluid, the analogy goes no further than its secretion into the open air, and its reabsorption into the system. The perspirable matter is another material secreted by animal glands into the external air, and is in part reabsorbed, and in part exhaled. And every other secreted fluid in the animal body is in part absorbed again into the system, even those which are esteemed excrementitious, as the urine ; and others are probably entirely reabsorbed, as the bile, saliva, and gastric juice.

That the honey is a nutritious fluid, perhaps the most so of any vegetable production, appears from its great similarity to sugar, and from its affording sustenance to such numbers of insects, which live upon it solely during summer, and lay it up for their winter provision. These proofs of its nutritive nature evince the necessity of its reabsorption into the vegetable system for some useful purpose.

3. It is probable, that the depredations of insects on this nutritious fluid must be injurious to the products of vegetation ; and would be much more so, but that the plants have either acquired means to defend their honey in part, or have learned to make more, than is absolutely necessary for their own economy. Thus in silene, catch-fly, and in drosera, sun-dew, it is defended by a viscid juice from the attack of insects ; in hellebore, and in aconite, it is defended by the difficult passage to it, and by the acrid juice of the plant, if insects should endeavour to creep into the nectary, or pierce it with their proboscis ; and in polygonum melampyrum, buck-wheat, and in calia suaveolens, alpine colts-foot, there seems to be a superabundant quantity of honey secreted, as those flowers are perpetually loaded with bees and butterflies, insomuch that at Kempton-land in Germany, Mr. Worlidge says, in his *Mysteries of Husbandry*, Ch. IX. 3. that he saw forty great bee-hives filled with honey to the amount of

seventy pounds in each in one fortnight by their being placed near a large field of buck-wheat in flower ; and I well remember being myself astonished at seeing the number of bees on a field of buck-wheat in Shropshire, as well as on a plant of *cacalia suaveolens* in my garden ; from which the scent of honey could be perceived at many feet distance from the flower.

In the same manner the honey-dew on trees is very injurious to them ; in which disease the nutritive fluid, the vegetable sap-juice, seems to be exuded by a retrograde motion of the cutaneous lymphatics, as in the sweating sickness of the last century, or is devoured by insects, which pierce the lymphatic vessels of the leaves at midsummer, feed on the vegetable chyle, and void it almost unchanged. See Sect. III. II. 8. and XIV. I. 7.

To prevent the depredation of insects on honey a wealthy man in Italy is said to have poisoned his neighbour's bees, perhaps by mixing arsenic with honey, against which there is a flowery declamation in Quintillian, No. XIII. This mixture of honey and arsenic may be used with effect to poison flies, which sometimes abound in pernicious multitudes ; for the flies which frequent our houses are liable to great thirst, as is seen by their drinking any fluid, which is diffused on a table ; whence if a slight solution of arsenic, with a little sugar, be put thinly on a plate or two, and set on chimney-pieces or windows, the flies will eagerly drink it, and perish almost instantly. It is probable that wasps might be thus destroyed in hot-houses, if a little honey was added to attract them by its odour.

As the use of the wax is to preserve the dust of the anthers from moisture, which would prematurely burst them, the bees, which collect this for the construction of the combs or cells, and collect the farina also probably for bee-bread for their larvæ or maggots, must on both these accounts also injure the vegetation of a country, where they too much abound.

4. It is not easy to conjecture, why it was necessary, that this secretion

tion of honey should be exposed to the open air in the nectary or honey-cup ; for which purpose so great an apparatus for its defence from insects and from showers became necessary. - This difficulty increases, when we recollect, that the sugar in the joints of grass, in the sugar-cane, and in the roots of beets, and in ripe fruits, is produced without exposure to the air. But on supposition of its supplying nutriment to the anthers and stigmas, it may thus acquire greater oxygenation for the purpose of producing the greater powers of amatorial sensibility, as mentioned in Sect. IV. 5. 6. and probably in this circumstance alone differs from sugar.

From this provision of honey for the male and female parts of flowers, and from the provisions of sugar, starch, and mucilage, in the fruits, seeds, roots, and alburnum of plants, laid up for the nutriment of the young progeny ; not only a very numerous class of insects, but a great part of the larger animals, procure their food. Surely this must be called a wise provision of the Author of nature, as by these means innumerable animals enjoy life and pleasure without producing pain to others ; for the embryos in these buds, seeds, or eggs, as well as the nutriment laid up for them, are not yet endued with sensitive life. There is another source of nutriment provided for young animals, which still further evinces the benevolence of the Author of nature ; and that is the milk furnished by the mother to her offspring ; by this beautiful contrivance the mother acquires pleasure in parting with a nutritious fluid, and the offspring in receiving it !

VII. 1. The wax is another vegetable secretion produced with the fecundating dust on the anthers of flowers, which in wet seasons it preserves from rain, to which it is impenetrable ; for the farina, or fecundating dust of plants, is liable to swell if exposed to much moisture, and to burst its shell ; and it either then becomes inert and ineffectual, or is washed away. Whence Mr. Wahlborn observes, that as wheat, rye, and many of the grasses, and plantain, lift up their anthers on long filaments, and thus expose the enclosed fecundating

dust to be washed away by the rains; a scarcity of corn is produced in wet summers; hence the necessity of a careful choice of feed-wheat; as that, which had not received the dust of the anthers, will not grow, though it may appear well to the eye.

2. A substance similar to this is said to be collected from extensive underwoods of the *cistus labdaniferus* in some eastern countries by this singular contrivance; long leathern thongs are tied to poles, and drawn over the flowers of these shrubs about noon, which thus collect the wax or resin with part of the anther dust, which adheres to the leathern thongs, and is occasionally scraped off for use. Thus in some degree the depredation of the bee is imitated, except that she loads her thighs only with the anther-dust, which according to Mr. John Hunter constitutes the bee-bread found in hives for the support of the larva or bee-maggot; and that she swallows the wax for the construction of her combs, as well as the honey for her winter provender; and thus every way injures the fecundity of flowers.

3. A wax in America is obtained from the *myrica cerifera*, candle-berry myrtle, the berries of which are boiled in water, and the wax separates. The seeds of the *croton sebiferum* are lodged in a kind of tallow; in both these plants the wax or tallow probably serves the purpose of preserving the immature seeds from moisture; or like the oil found in flax-seed, rape-seed, and in many kernels, they may constitute in part the nourishment of the new plant.

It must nevertheless be observed, that Mr. Sparman suspects, that the green wax-like substance on the berries of the *myrica cerifera* is deposited by insects. Voyage to the Cape, V. I. p. 145. And Du Halde describes a white wax made by insects in great quantity round the branches of a tree in China, which is called Tong-tsin. Descript. of China, V. I. p. 230. And lastly, sir G. Staunton mentions a white wax on a plant in Cochin-China, which he believes to be strewed on the plant in the form of white powder, which has this singular property, that one part of this white powder mixed with three parts of

olive oil made hot, gave it when cold the consistence of bee's-wax. *Embassy to China, Vol. I. p. 354.*

VIII. 1. Turpentine or balsams, resins, and essential oils, are analogous to the vegetable secretions last mentioned; in their being inadmissible with water. Those vegetables, which contain in their vessels the least water, bear cold climates the best; because when water is frozen, it occupies more space than before; and hence bursts the bottles which contain it; in the same manner when any succulent vegetable is frozen, its vessels become burst or bruised by the expansion of the ice, and the plant is destroyed; on this account those parts of plants, which are the most juicy, as the last shoots of vines, are soonest destroyed in winter. Hence many of the evergreen trees of this climate are replete with turpentine or resin, which by occupying the place of so much water, contributes to their hardness. There is also a partial secretion of balsam or turpentine in many deciduous plants for the purpose of defending their buds during the winter, both from frost and from wet, which is repelled by their balsamic varnish, as on the buds of the *populus tacamahacca*.

2. The balsams and resins of the shops are either extracted from the wood by fire, or exude from wounds of the tree; thus what is called Venice turpentine is obtained from the larch by wounding the bark about two feet from the ground, and catching it as it exudes. Sandarach is procured from common juniper, and incense from another juniper; and there is reason to believe that bitumen, or petroleum, with jet, amber, and all the fossil coal in the world, owes its inflammable part to the recrements of destroyed forests of terebinthinate vegetables, so important to the present race of mankind has been this vegetable secretion!

3. The essential oils are sometimes raised by distillation from balsams or resins, as oil of turpentine; but are chiefly extracted from flowers; where their office has been to prevent the depredations of insects; though many of them are so agreeable to the human sense of smell,

smell, when these essential oils are dissolved or mixed with water in distillation, they have been called the spiritus rector of the plant, and constitute the odour of it, whether aromatic or fetid.

Some of these essential oils possess the most poisonous qualities, as those of lauro-cerasus, and of tobacco; and are used by Indian nations for the purpose of poisoning their weapons, which they cover like a varnish. And hence some of the resinous woods are said never to be devoured by insects, as the unperishable chests of cypress, in which the Egyptian mummies have been preserved for so many ages, and the cedar in which black lead is inclosed for pencils.

The acrid poison of the large euphorbium of Africa exists in the oil of that plant; as M. Vaillant observes, that the natives sometimes poison the waters with slicing this plant into them, and that the poisonous oil swims upon the surface, and may thus be avoided by a careful drinker. This in a country where water is scarce, and generally in stagnant pools, may be readily effected; as a few spoonfuls of oil will cover a large sheet of water, as it becomes diffused upon it without friction, as mentioned in Botanic Garden, Vol. I. Addition. Note XXIX.

4. Some of the essential oils are so inflammable as to burst into a vehement flame on being mixed with nitrous acid, as oil of cloves; and even the small quantity diffused in the air round the dictamnus fraxinella will take fire on a still evening at the approach of a lighted candle.

5. With these should be arranged the elastic resin called Caoutchouc, which is said to exsude from a tree in Guiana, called *Iatropa elastica*, by M. de la Borde, physician at Cayenne. A similar elastic resin is said to be obtained from a plant in Madagascar, called *Einguere*, a kind of wild fig-tree, according to Abbe Rochon; and the bird-lime extracted from the bark of the hollies of our climate seems to be a similar material; as like the caoutchouc it becomes soft by heat, and is impenetrable by water, but soluble in ether. Another elastic substance,

stance, which is insoluble in water, is procured from wheat by long mastication, or by agitating the flour of it in water; which has been said to approach to animal matter, and is believed to be the most nutritious part of that aliment, and was once much talked of, or sold under the name of alimentary powder for the nourishment of marching armies.

IX. 1. The bitter, narcotic, and acrid juices of plants are secreted by their glands for the defence of the vegetable from the depredation of insects and of larger animals. Opium is found in the leaf, stalk, and head of the poppy; but not in the seeds. A similar narcotic quality exists in the leaf and stem of hyoscyamus, henbane, but not in the seeds. An acrid juice exists in husks of walnuts, and in the pellicle, or skin, of the kernel; but not in the lobes, or nutritious part of it. These seem to have been excluded from the seed, lest they might have been injurious to the tender organs of digestion of the embryo plant. In some seeds, however, there is a bitter quality, but which refuses to mix with the oleagenous part; as the oil expressed from bitter almonds is as tasteless as that from the sweet almonds.

2. Other vegetables possess glands adapted to the secretion of various fluids more or less aromatic, acrid, or astringent; as the herb of water-cress, the root of horse-radish, the seeds of mustard, the flowers of roses, the fruit of quince, and the bark of oak. To these should be added those which have emetic and cathartic qualities; and other vegetable preparations, which are used in the arts of dying, tanning, varnishing; and which supply the shops of the druggist with medicines and with poisons. All which deleterious juices seem to have been produced for the protection of the plant against its enemies, as appears by the number of poisonous vegetables, which are seen in all our hedge-bottoms and commons, as hyoscyamus, cynoglossum, jacobæa, and common nettles; which neither insects nor quadrupeds devour, and which are therefore of no known use but to themselves; and possess

possess a safer armour in this panapoly of poison, than the thorns of hollies, briars, and gooseberries.

3. As the bitter, narcotic, acrid, and terebinthinate, as well as the farinaceous, oily, and saccharine matters, are secreted in summer from the vegetable blood, and reserved for the nutrition and defence of the new buds and bulbs, they are in this climate generally found more concentrated in the hybernaculum, or winter-lodge of plants, before the new sap is raised by the umbilical or absorbent vessels in the spring. Hence roots and barks, as well as fruits and seeds, are best collected in autumn, or in winter, for the purposes of medicine or of other arts.

Thus the bark of oaks should be taken off for the use of the tanner in the winter, or in early spring, before the leaves pullulate, as then a great part of its astringent or bitter juices is reabsorbed, and carried to the new foliage along with the saccharine sap-juice, which has been deposited in the cells of the alburnum or sap-wood. But as the barks of trees become looser, and much more easily detached from the wood, when the sap-juice rises in the spring, this is the best time for debarking them; but the naked bole and branches should stand till autumn, till the saccharine matter collected in the alburnum has been expended in unfolding the new leaves; otherwise it will soon ferment and putrefy; and the sap-wood will thus quickly decay by what is termed the dry-rot of timber, as mentioned in Sect. III. 2. 3.

X. 1. The acids produced by vegetable secretion have of late been much subjected to chemical inquiry, and have been found to be so numerous, that they have been named from the vegetables, or parts of vegetables, from which they have been extracted; as the gallic acid, malic acid, oxalic acid. Many unripe fruits contain an austere acid, which is gradually converted into sugar by vegetable or chemical processes for the nutriment of their seeds, as described in No. V. 4. of this section. In other plants it exists in the foot-stalks of the leaves,

as in rheum, rhubarb; or in the leaves themselves, as in oxalis, sorrel; in these situations also I suppose it is secreted both for the defence of those plants from the depredation of insects and of larger animals; and also for the purpose of its being converted into a saccharine juice by the digestion of the young bud in the bosom of the leaf.

S E C T. VII.

THE ORGANS OF REPRODUCTION OF VEGETABLES.

The theory of Linneus for vegetable reproduction too mechanical, and without analogy. Every new fluid is secreted by glands, as the liquor amnii and albumen ovi. So also is the favilla vitæ, or living entity. I. 1. Lateral progeny. The new bud is secreted in the axilla of the leaf, and requires no female apparatus. It adheres to its parent not by inosculation of vessels, but resembles the chick in the egg. 2. Difference of the chick and fetus. Their nutriment and oxygenation. The embryo may be seen in the buds of horse-chestnut. It is a paternal progeny. 3. This lateral offspring resembles the parent. Not universally so. More perfect than seeds. Buds of diacious plants bear similar sexes. The lateral progeny degenerates from hereditary diseases. Whence curled potatoes, blighted strawberries, bears fruit at the same time, and of the same kind. Plants live longer if prevented from flowering. Art of producing double hyacinths, ranunculus, tulips. 4. Lateral progeny of corallines and sea-anemonies. Polypi are all males. Wires of knot grass like the joints of the tape-worm, which are all males. 5. Aphis, viviparous and oviparous like vegetable generation. 6. Vessels of the bud and leaf do not inosculate. Viviparous, oviparous, and paternal generation. 7. Leaves on twigs like the progeny of volvox. But in some twigs the pith is divided, and the buds successive. Hermaphrodite generation. Buds from every part of the caudex. Those from below the graft are like the stock. Find numerous uteri like eggs and spawn. Paternal generation preceded sexual generation. The last more excellent. II. 1. Sexual progeny. Seeds before impregnation. Eggs before impregnation. Seed-embryon suspended by opposite points like the cicatricula of the egg. 2. Seed-bud and flower. Stamens and stigmas. Males bend to females, and females to males. Style of spartium bends round like a French horn. Onanism of epilobium. Male flowers of vallisneria swim to the females. Flowers with long filaments injured by rain. Submarine plants project a liquor. 3. The petals are respiratory organs. 4. Honey is the food of the anthers and stigma; which like butterflies propagate and die.

N

5. Seeds

5. Seeds are formed and nourished by the umbilical vessels previous to fecundation, or by the bractes or floral-leaves. Dispersion of seeds by plumes, by books, by twisted awns. Creep on the ground. Hygrometer of a geranium seed. 6. Sexual generation the chef d'œuvre of nature. Produces variety of species. Mixed breed of cabbage. Mixed breeds of beans. An apple sour on one side. Vegetable mules. 7. Animal mules. They externally resemble the male, internally the female. Mule from the horse and female ass. From the mare and male ass. From Spanish rams and Swedish ewes, and the contrary. From the goat of angora. Ram without horns. 8. How to improve the varieties of fruits and flowers, and produce new ones. Many plants were originally mules, and many animals. How to produce new animal monsters, both quadrupeds and fish, by the method of Spallanzani. Mules more frequent in antient times. III. Vegetable generation. 1. A triple tree by ingraftment. The caudex of each bud is triple. Lateral or paternal mules. *Conferva fontinalis* splits. 2. The lateral propagation of the polypus. The hydra *stentorea* splits. Two halves of different polypi unite. So the vegetable filaments or caudexes in ingrafted trees. 3. Triple lateral mule. Each part of the triple caudex is produced from that in its vicinity, not from the plumula of the bud. 4. Worms multiplied by dividing them. So the caudexes of the buds of trees. 5. The parts of the long caudexes of trees are secreted from the adjoining parts of the parent caudexes, and combine beneath the cuticle of the tree. Every part of a compound caudex can produce a new bud, resembling the part of the compound stock, where it rises. Lateral mules consist of parts from three or four parents. Could there be a threefold sexual mule? 6. Power of attraction. Aptitude to be attracted. Chemical combinations by single attraction. By double affinity. 7. Union of animated bodies with inanimate matter, as in swallowing food. In absorption by the lacteals. Vitality of the blood. Fibrils with nutritive appetencies. Molecules with nutritive propensities. 8. Fibrils with formative appetencies, and molecules with formative propensities secreted beneath the cuticle of trees, and coalesce. Hunger and love, thirst, suckling children, they reciprocally stimulate and embrace each other. 9. Great secret of nature. Formative or nutritive particles in the blood more than necessary. Secreted by numerous glands. Arranged under the cuticle of trees. Acquire new appetencies, and produce new parts. 10. In sexual generation they are secreted by two glands only. Those of the anther and pericarp unite in the matrix. 11. Without formative molecules as well as formative fibrils

there could be no mules, or any resemblance to the mother. The new doctrine of threefold vegetable mules applied to animal generation. 12. Conclusion.

THE theory of Linneus in respect of the reproduction of vegetables maintains, that the internal medullary part must be joined with the external or cortical part of the plant for the purpose of producing a new one. If the medulla be so vigorous as to burst through its containing vessels, and thus mix with the cortical part, a bud is produced either on the branches or roots of vegetables; otherwise the medulla is extended, till it terminates in the pistillum, or female part of the flower; and the cortical part is likewise elongated, till it terminates in the anthers, or male part of the flower; and then the fecundating dust from the latter being joined to the prolific juices of the former, produces the seeds or new plants; at the same time the inner rind is extended into the corol or petal, and the outer bark into the calyx.

After the seeds are thus produced, the parent bud dies; and in this respect the buds bear a very great analogy to those annual insects, which change from their caterpillar or larva-forms, putting forth painted wings and organs of reproduction, and after depositing their eggs cease to exist. See the account of the vegetable kingdom by Linneus, prefixed to the system of vegetables translated by a botanical society at Lichfield. Leigh and Sotheby, London.

However simple and ingenious the first part of this theory may appear, in which the medulla is supposed to extend itself, till it bursts the inclosing or cortical part, and joining with that produces a new bud; yet it seems too mechanical for a living organized system; and so totally different from any thing we know of sexual production either in animals or flowers, as not readily to satisfy a reasoning mind.

Every new fluid or solid produced in the organic system of vegetable or animal bodies is secreted from their blood, as the various fluids

of bile, saliva, tears, in animals ; and those of gum, resin, sugar, in vegetables. Amongst these are the juices which constitute the nutritious fluid of the amnios in the uterus of viviparous animals, or that of the albumen of the egg in oviparous ones. And lastly, the *flavilla vitæ*, the new spark of being, or living entity, is also secreted from the blood of male animals by adapted glands to be received into a proper nidus, and nourished by the female.

I. LATERAL PROGENY.

1. As the leaf with its petiole, or foot-stalk, and its caudex down the bark of a tree, with its radicle beneath, constitutes an individual plant ; and the bud in its bosom succeeds, and is evidently produced by it ; it may be concluded from the strongest analogy that this new progeny is secreted from a gland or glands of the parent ; and that, as it adheres to the parent, it requires no female apparatus for its reception, nourishment, or oxygenation.

I was formerly induced to believe, that there was a communication of blood, or inosculation of vessels between the parent leaf, and the new bud in its bosom, as expressed in *Zoonomia*, Sect. XXXIX. 2. 2. and that this constituted the difference between paternal gestation and maternal gestation. But that the vessels between the new bud and the parent leaf-bud do not inosculate may be well seen by taking away the bark of the foot-stalk of a leaf, and of the new bud in its bosom ; as the remains of the arteries of the late leaf, as well as the rudiment of the new bud, are seen to terminate in the alburnum, or to penetrate the pith, but without any apparent communication ; and I therefore suspect, that the embryo bud is not served with vegetable blood from the vessels of the parent, but that it acquires both nutriment and oxygenation much in the same manner as the chick in the egg. See Sect. III. 1. 5.

2. The condition of the chick in the egg differs from that of the fetus

fetus in the womb of viviparous animals in the whole of its nutriment being at first provided for it, which consists of the albumen, or white of the egg, which is contained in cells, and is of different degrees of consistency, that which is most fluid being first consumed; whereas the liquor amnii, or nutriment of the fetus in utero, is gradually secreted by adapted glands from the blood of the mother, as it is wanted.

Another difference between the condition of the chick and of the fetus consists in the manner, by which their blood acquires its necessary oxygenation. In the fetus this is done by means of the placental vessels, whose extremities are inserted into the blood-vessels of the uterus, and receive oxygen through their moist membranes from the passing currents of the mother's blood, as described in *Zoonomia*, Vol. I. Sect. XXXVIII. Whereas in the egg after a few days incubation a membrane is seen, which includes the albumen, and spreads the extremities of its fine blood-vessels on the moist membrane, which covers the air at the broad end of the egg; which air is occasionally renewed, as would appear by its being seen so easily to pass through the shell, when an egg is covered with water in the exhausted receiver of an air-pump.

The condition of the embryo bud, when the parent leaf-bud dies, I conceive to be similar to that of the chick in the egg, when that is separated from its parent. Each of them has at this time a reservoir of nutriment provided for it; that of the chick consists of the albumen, or white of the egg above mentioned; and that of the bud consists of mucilage and sugar, which are deposited in the alburnum or sap-wood, or in the roots of the plant. And secondly, I conceive that the extremities of a fine system of vessels belonging to the bud may terminate on the moist membrane, which covers the horizontal air-vessels described in Sect. III. 2. 6. as those on the chorion of the chick terminate on the air-bag of the egg, and thus acquire the necessary oxygenation of their vegetable blood.

This

This analogy between the vegetable and animal fetus in respect to their production, nourishment, and oxygenation, is as forcible in so obscure a subject, as it is curious; and may in large buds, as of the horse-chestnut, be almost seen by the naked eye. If with a penknife the remaining rudiment of the last year's leaf, and of the new bud in its bosom, be cut away slice by slice, the seven ribs of the last year's leaf will be seen to have arisen from the pith in seven distinct points, making a curve; and the new bud to have been produced in their center, and to have pierced the alburnum and bark, and grown without the assistance of a mother.

And lastly, by in part cutting, and in part tearing, the pith and alburnum from the bottom of a new leaf-stalk of horse-chestnut about the middle of May, an oval prominence may be seen in the internal part of the leaf-stalk, which fills up a space between the vessels of the bottom of the leaf-stalk and those of the new bud, and seems to connect them by its extremities, and to press on the pith beneath it. From this apparent gland I conjecture that the now living fibres, or animalcules, are probably secreted, which form the new bud adhering to the pith, and nourished by the parent leaf; that thus a paternal progeny is produced without the assistance of a mother.

3. This paternal offspring of vegetables in their buds and bulbs is attended with a very curious circumstance; and that is, that they exactly resemble their parents, as is observable in grafting fruit-trees, and in propagating flower-roots; whereas the feminal offspring of plants, being generated by two parents, and certainly supplied with nutriment by the mother, is liable to perpetual variation. This also in the vegetable class diœcia, where the male flowers are produced on one tree, and the females on another, the buds of the male trees uniformly produce either male flowers, or other buds similar to themselves; and the buds of the female trees either produce female flowers, or other buds similar to themselves; whereas the seeds of these trees produce either male or female plants. See Sect. III. 2. 1.

This

This similitude of buds and bulbs to their parents is to be understood only to exist after the maturity of the plant, that is after it has produced a sexual offspring in flowers and seeds; for a bulb, as of a tulip, and a bud of a fruit-tree, when first raised from their seeds, are very small, but produce one or more improved bulbs, or improved buds annually, for some years; which differ from their parent bulbs or buds in the size, form, and colour of their leaves, till it arrives at its maturity, or acquires the power of generating a sexual progeny; from whence it appears, that the leaf-buds of those trees, and the leaf-bulbs of those roots, which have acquired their puberty, if it may be so called; that is, their power of generating flowers, are a more perfect progeny than the seeds of those plants, as these latter, when separated from their parent either by transplantation or by ingrafting, can immediately produce seeds, or a sexual progeny; but the buds from many seeds are some years before they can produce seeds. The same is probably true of many annual or biennial plants, as of wheat; which produce many successive buds upon each other previous to the flower-bud, as appears by the joints of the stem; all which may be considered as individual plants growing on each other like the annual succession of the buds of trees.

Another curious occurrence in this lateral production of vegetables by their buds has been lately published by Mr. Knight in the *Phil. Transf.* for the year 1795, who observes, that those apple-trees, which have been continually propagated for above a century by ingrafting, are now become so diseased by canker, or otherwise, that though the fruit continues of the same flavour, the trees are not worth propagating; as these grafts, though transplanted into other trees, he esteems to be still an elongation of the original tree, and must feel the effect of age like the tree they were taken from. If this idea should prove true on further examination, there is reason to suspect the same may occur in the too long propagation of plants from bulbs and wires, as potatoes and strawberries, which may have occasioned the curled tops of potatoes,

toes, and the black blight in the flowers of the hautbois strawberry, which some have ascribed to its only bearing male flowers; the cure of which must arise from our applying to other varieties more lately derived from a feminal offspring.

This degeneracy of trees or perennial herbaceous plants propagated by buds or root-scions is not I think to be ascribed simply to the age of the original seedling-tree, because each successive generation of buds or bulbs are as distinct from the parent, as the generation by seeds. But as the lateral progeny of vegetables have no source of improvement after they have arrived at their maturity, but are liable like other plants and animals to injuries from food and climate, which injuries produce hereditary diseases, it is to this circumstance that their degeneracy ought rather to be ascribed; whereas the sexual progeny of vegetables are liable to improvement by the intermixture of the individuals of the same, or even of different species to counteract the effects of hereditary diseases.

Another curious similarity which buds bear to their parent tree is also observed by Mr. Knight, Phil. Transf. for 1795. Part II. p. 292. "Cuttings from seedling apple-trees of two years old were inserted on stocks of twenty years old, and in a bearing state; but these have now been grafted nine years; and, though they have been frequently transplanted to check their growth, they have not yet produced a single blossom. I have since grafted some very old trees with cuttings from seedling apple-trees of five years old. Their growth has been extremely rapid, and there appears no probability that their time of producing fruit will be accelerated, or that their health will be injured by the great age of the stocks. A seedling apple-tree usually bears fruit in thirteen or fourteen years; and I therefore conclude, that I have to wait for a blossom, till the trees, from which the grafts were taken, attain that age; though I have reason to believe from the form of their buds that they will be extremely prolific. Every cutting therefore taken from the apple, and probably from every

every other tree, will be affected by the state of the parent stock. If that be too young to produce fruit, it will grow with vigour, but will not blossom; and if it be too old, it will immediately produce fruit, but will never make a healthy tree, and consequently never answer the intention of the planter.

“The durability of the apple and pear I have long suspected to be different in different varieties; but that none of either would vegetate with vigour much, if at all, beyond the life of the parent stock, provided that died from mere old age. The oak is much more long-lived in the north of Europe than with us, though the timber is less durable; the climate of this country, being colder than its native one, may in the same way add to the durability of the elm; which may possibly be further increased by its not producing seeds in this climate; as the life of many annuals may be increased to twice its natural period, if not more, by preventing their seeding.”

It is observed above, that the first bulb of a tulip raised from seed produces a more perfect bulb annually for five or six years, and perhaps more than one less perfect ones, before it acquires the power of generating seeds. Now when this period arrives, if the seed-stem be pinched off, I suppose that the next year's bulb or bulbs will become more vigorous or luxuriant, and if this be continued for three or four years I suspect the double flowers, which are perhaps owing to a more luxuriant growth, may be formed; and that in this, with superfluous nourishment by manure, warmth, and moisture, consists the art of obtaining hyacinths, ranunculus, and sometimes tulips, with such wonderful multiplication of petals or nectaries. See Sect. XIX. 3. 1.

4. The analogy, which exists between this lateral production of vegetables and that of some tribes of insects, is worth investigation.

1. This paternal or lateral generation of plants, which constitutes the buds on the stems of trees, and the scions on their roots, which continue to adhere to them, are so far resembled by the branching insects, which form the corals or corallines; and by many other sea-

animals, as the sea anemonies, which are said to adhere to the shores, or submarine earth, by one extremity, while they pullulate, or spread out by the other into living ramifications of unmeasurable lengths.

Those who have attended to the habits of the polypus, which is found in the stagnant water of our ditches in July, affirm, that the young ones branch out from the side of the parent like the buds of trees; and after a time separate themselves from them. This is so analogous to the manner in which the buds of trees appear to be produced, that these polypi may be considered as all male animals, producing embryos, which require no mother to supply them with a nidus, or with nutriment and oxygenation.

Secondly, this paternal or lateral vegetable progeny is beautifully seen in the wires of knot-grass, *polygonum aviculare*.; and in those of strawberries, *fragaria vesca*; and in the roots of potatoes. The lateral generation of these plants by wires, while each new plant is thus chained to its parent, and continues to put forth another and another, as the wire creeps onward on or beneath the ground, is exactly resembled by the tape-worm, or *tænia*, so often found in the bowels, stretching itself in a chain quite from the stomach to the rectum. Linneus asserts, "that it grows old at one extremity, while it continues to generate young ones at the other, proceeding ad infinitum, like a root of grass. The separate joints are called gourd-worms, and propagate new joints like the parent without end, each joint being furnished with its proper mouth and organs of digestion." *Systema Naturæ*, vermes, *tenia*. In this animal there evidently appears a power of reproduction without any maternal apparatus for the purpose of supplying nutriment and oxygenation to the embryo, as it remains attached to its father till its maturity, and in this respect exactly resembles the lateral generation of vegetables.

5. This subject of the lateral production of vegetables from male parents without the intervention of a female is further resembled by the innumerable progeny of the aphid, which rises from an egg in the spring,

spring, as a vegetable rises from a seed, and produces a viviparous offspring for many generations like the successive buds of a seedling apple-tree, or of a seedling tulip; and then it generates both males and females, which copulate and deposit eggs, like the anthers and stigmas of flowers, and their consequent seeds; which at length appear on seedling apple-trees and on seedling tulips; as is further spoken of in Sect. IX. 2. 7. and XIV. 1. 6.

6. Whence I conclude, that in sexual viviparous generation the new entity, or embryo, is secreted by the male, and received into a nidus prepared for it by the female, and nourished by fluids secreted into the uterus, as they are required, which is probably owing to the stimulus of the fetus against the sides of it; that in sexual oviparous generation a reservoir of nutriment is prepared, and inclosed in the egg, previous to the reception of the embryo, which is secreted by the male, and deposited in this reservoir of nutriment; because the fetus in these animals is to be separated from the parent before its due maturity; and the egg, in which it is inclosed, may be considered as an uterus, or womb, separated from the mother. And lastly, that in paternal or male generation the new entity, or embryo, is as certainly secreted from a gland of the male, but probably remains in an adapted reservoir belonging to this gland, correspondent to the *vesiculæ feminales* of most viviparous animals, and that here it exists like the *cicatrix* in the egg, and has a reservoir of nutriment prepared for it like that in the egg to support it; when the paternal leaf-bud by its death is separated from it in the autumn, as the egg is separated from its living mother.

7. The production of buds in the axilla of every leaf may thus be easily conceived, as the new buds are furnished with their caudexes or bark-filaments over those of their dead parents, which shoot out root-fibres beneath in the ensuing spring, and that I suppose both in deciduous plants and in evergreens; as in the latter also I believe the parent leaf-bud annually falls off, though not by the immediate in-

fluence of the cold of autumn. But how long a twig or scion of leaves, as in the vine or willow, succeed each other, some producing embryo buds in their bosoms before others become expanded, is not easy to understand; but the embryos of all these new leaves, though not of the buds in their bosoms, probably existed in the paternal womb, though in different degrees of maturity, which accords with the observations of some naturalists on the successive generations of the *volvex globator*, which Linneus asserts to be diaphanous, and that it carries within itself sons and grandsons to the fifth generation, but which are probably living fetuses produced by the father, of different degrees of maturity, and to be detrued at different periods of time like the unimpregnated eggs of various sizes, which are found in poultry. See *Zoonomia*, Vol. I. Sect. XXXIX. 2. and *Linnei System. Naturæ. Vermes. Volvox*.

In some trees however, as in the vine, *vitis*, and in many herbaceous plants, as in wheat, southistle, teasel, *triticum*, *sonchus*, *dypfacus*, each successive joint of the plant is evidently an individual vegetable being; because the pith, which constitutes the brain or spinal marrow of each individual, terminates at every joint by a division, as spoken of in Sect I. 8. whence in these vegetables every successive joint appears to be produced by that beneath it; whereas where there is no division of the pith, the twig seems to be simply an elongation of the caudex of the leaf-bud, like the wires of strawberries and other creeping plants.

It should nevertheless be added, that there are many hermaphrodite insects, as shell-snails and dew-worms, which contain both male and female organs of generation; and as they are perpetually seen to copulate with each other, it is believed, that they can not impregnate themselves. Now it may be conceived, that the buds of trees possess both male and female organs of generation, and that they can impregnate themselves, and that thus the new buds might be termed an hermaphrodite offspring rather than a paternal one. This would
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however produce a confusion of terms, as the eggs of snails and of worms, as mentioned above, are properly an hermaphrodite offspring.

Another circumstance occurs in this paternal generation, which differs from that of those hermaphrodite insects above alluded to, which is, that though in vegetables the new embryo is generally produced in the bosom of the leaf-stalk, which is believed to be its parent; yet new buds are occasionally protruded from almost any part of the bark, when the summit of a branch is taken off, or the side branches of a tree, so as to admit light and air, and a supply of more nutriment; whence it would seem, that though hermaphrodite insects possess but one male and one female apparatus for the production and reception of the new entity or embryo, yet that in paternal generation the prolific fluid is occasionally secreted in any part of the caudex of each individual bud from its summit on the branch of a tree to its termination in the root; and that wherever a proper nidus can be found, which is supplied with nutriment, and exposed to light and air, that there the new embryo can adhere and grow; although this occurs most conveniently, and thence most frequently, in the bosom of the leaf-stalk, where the prolific fluid is probably first secreted, and the nutriment most copiously supplied from the vegetable blood newly oxygenated in the leaf. In this I suppose to consist the great difference between paternal and sexual generation; and that this mode of reproduction forms an exception to the general axiom of the great Harvey, "all things from eggs."

The existence of a power of generation in every part of the caudex of a vegetable bud from the summit to the root is not only shewn by the new buds, which grow on the trunks of trees, which were felled in the spring, but also from a curious circumstance which occurs in ingrafted trees; which is, that whenever after many years any new buds or scions grow from the stock beneath the graft, it is always similar to the parent stock, and not to the ingrafted scion; which
shews,

shews, that this new bud was generated in the old stock, and not that it was owing to an absorption and deposition of a prolific fluid secreted in any part of the ingrafted head. It must however be remembered, that the caudex of each bud extends from the leaf-stalk to the root, whether it be a simple caudex as in a seedling tree, or a compound one as in a grafted tree; and that the generation of new buds in perennial herbaceous plants exists in every part of the broad caudex on the root, as it does here in every part of the long caudex on the trunk. Nothing known in the animal world resembles this universality of the generative faculty throughout almost the whole of an individual vegetable being, except the number of new polypi said to arise at the same time from different parts of the same individual animal.

Wherever the new vegetable embryos are secreted, they also find a situation or uterus, where they can adhere and be nourished to almost any number; which however is not unsupported by some analogy even in viviparous animals; as there have been many instances of extra-uterine fetuses, which have attached or inserted their vessels into the peritoneum, or on the viscera of the mother, in the same manner as they naturally attach or insert them into the sides of the true uterus. And in respect to the number of uteri produced we may recollect the number of eggs, and of fish-spawn, or frog-spawn, or of seeds, which may all be termed so many distinct uteri, as they contain every thing, which is found in the uteri of viviparous animals.

The aphis, and probably many other insects, possess both the solitary and sexual mode of propagation, as is possessed by most vegetables; but the polypus and tenia, and hydra stentorea, and volvox, appear only to be reproduced by the solitary or lateral generation; and it is probable that the truffle amongst vegetables, and some submarine plants, and others of the class cryptogomia, whose seeds have not been yet discovered, may still be only propagated by the
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lateral mode of reproduction, as is well observed in an ingenious work by a lady of very accurate botanic knowledge, called "Botanic Dialogues, designed for the use of schools," one volume octavo, Johnson, London; but which may be strongly recommended to the adult in botany as containing much useful information agreeably imparted.

This curious subject of lateral or solitary generation is well worthy more accurate investigation, as it is the simplest, and was probably the first mode of reproduction which existed; and if any accurate knowledge can ever be acquired of animal generation, it will possibly occur from a more nice attention to the production of the buds and bulbs of vegetables! which is further spoken of in Sect. IX. 2 and 3. At the same time it must be observed, that the sexual reproduction is the *chef d'œuvre*, the master-piece of nature, as by the paternal or lateral reproduction the same species only are propagated ad infinitum; whereas by the sexual mode of reproduction a countless variety of animals are introduced into the world, and much pleasure is afforded to those, which already exist in it.

II. SEXUAL PROGENY.

1. We come now to the feminal mode of the production of vegetables, which originates from the congress of the male and female parts of flowers, and may be therefore termed the sexual or amatorial progeny of vegetation.

From the accurate experiments and observations of Spallanzani it appears, that in the *Spartium Junceum*, rush-broom, the very minute seeds were discerned in the pod at least twenty days before the flower is in full bloom; that is, twenty days before fecundation. At this time also the powder of the anthers was visible, but glued fast to their summits. The seeds however at this time, and for ten days after the blossom had fallen off, appeared to consist of a gelatinous substance.

substance. On the eleventh day after the falling of the blossom the seeds became heart shaped, with the basis attached by an appendage to the pod, and a white point at the apex; this white point was on pressure found to be a cavity including a drop of liquor.

On the twenty-fifth day the cavity, which at first appeared at the apex, was much enlarged, and still full of liquor; it also contained a very small semi-transparent body of a yellowish colour, gelatinous, and fixed by its two opposite ends to the sides of the cavity.

In a month the seed was much enlarged, and its shape changed from a heart to a kidney; the little body contained in the cavity was increased in bulk, and was less transparent, and gelatinous, but there yet appeared no organization.

On the fortieth day the cavity now grown larger was quite filled with the body, which was covered with a thin membrane; after this membrane was removed, the body appeared of a bright green, and was easily divided by the point of a needle into two portions, which manifestly formed the two lobes; and within these attached to the lower part the exceedingly small plantule was easily perceived.

The foregoing observations evince, 1. That the seeds exist in the ovarium many days before fecundation. 2. That they remain for some time solid, and then a cavity containing a liquid is formed in them. 3. That after fecundation a body begins to appear within the cavity fixed by two points to the sides, which in process of time proves to be two lobes containing a plantule. 4. That the ripe seed consists of two lobes adhering to a plantule, and surrounded by a thin membrane, which is itself covered with a husk or cuticle. Spallanzani's Dissertations, Vol. II. p. 253.

The analogy between seeds and eggs has long been observed, and is confirmed by the mode of their production. The egg is known to be formed within the hen long before its impregnation. C. F. Wolf asserts, that the yolk of the egg is nourished by the vessels of the mother, and that it has from those its arterial and venous branches; but

but that after impregnation these vessels gradually become imperious and obliterated; and that new ones are produced from the fetus, and dispersed into the yolk. Haller's *Physiol.* Tom. VIII. p. 94. The young seed after fecundation I suppose is nourished in a similar manner from the gelatinous liquor, which is previously deposited for that purpose; the uterus of the plant producing or secreting it into a reservoir or amnios, in which the embryo is lodged; and that the young embryo is furnished with vessels to absorb a part of it, as in the very early state of the embryo in the egg.

Another curious analogy seems to exist between the embryo of the seed and of the egg in their mode of suspension. The cicatrix of the egg rests on the yolk, which is suspended by two points, called *chalazæ*, somewhat above its center of gravity; whence, however the egg is moved, this embryo is always kept upwards, probably the better to receive the warmth of the mother during incubation. The seed-embryo seems to be supported in the same manner by the above relation of Spallanzani by two points, and may thus receive a greater warmth from the summer sun.

2. The seeds are thus produced in their unimpregnated state in the vegetable uterus, and nourished by the flower-bud, which was formed in the deciduous trees of this climate during the preceding summer, and which now puts forth the bractes, or floral-leaves, for the oxygenation of its blood; and protrudes its roots and absorbents into the ground from the lower part of its caudex, for the purpose of acquiring nourishment; and on the summit of this sexual apparatus are at the same time produced the corol and nectaries of the flower, with the stamens, and stigmas, which are evidently designed to give fecundation to the vegetable seeds, or eggs, previously deposited in the pericarp or uterus; because, as soon as these are impregnated, the corol and nectaries, with the stamens, and stigmas, fall off and disappear.

The anthers have been proved by many experiments to be necessary to the fecundation of the vegetable seeds by the farina, or dust,

which they disperse, and which adheres to the moist stigma on the summit of the style or pericarp. The amatorial attachment between these stigmas and the anthers on the summits of the stamens has attracted the notice of all botanists. In many flowers the anthers or males bend into contact with the stigmas or females, as in *kalmia*, *fritillaria perfica*, *parnassia*, *cactus*, and *cistus*. In the *kalmia* the ten stamens lie round the pistil, like the radii of a wheel, and each anther is concealed in a nich of the corol to protect it from cold and moisture; these anthers rise separately from their niches, and approach the stigma of the pistil for a time, and then recede to their former situations. In the *fritillaria perfica* the six stamens are of equal lengths, and the anthers lie at a distance from the pistil; of these three alternate ones approach first, and surround the female; and when these decline, the other three approach; and in *parnassia* the males alternately approach and recede from the female; and lastly in the most beautiful flowers of *cactus grandiflorus*, and of *cistus labdaniferus*, where the males are very numerous, some of them are perpetually bent into contact with the female; and as they recede, others advance.

In other flowers the females bend into contact with the males, as in *nigella*, *epilobium*, *spartium*, *collinsonia*. In *nigella*, devil in the bush, the females are very tall compared to the males, and bending down over them in a circle, give the flower some resemblance to a regal crown. The female of the *epilobium angustifolium*, willow-herb, bends down amongst the males for several days, and becomes upright again when impregnated. In the *spartium scoparium*, common broom, the males or stamens are in two sets, one set rising a quarter of an inch above the other. The upper set does not arrive at their maturity so soon as the lower; and the stigma, or head of the female, is produced amongst the upper or immature set. But as soon as the pistil grows tall enough to burst open the keel-leaf, or head of the flower, it bends itself round in an instant like a French horn,
and

and inserts its head, or stigma, amongst the lower or mature set of males. The pistil or female then continues to grow in length; and in a few days the stigma arrives again amongst the upper set, by the time they become mature. This wonderful contrivance is readily seen by opening the keel-leaf of the flowers of broom, before they burst spontaneously. And lastly, in the collinsonia the two males widely diverging from each other, the female bends herself into contact first with one of them; and after a day or two leaves this, and applies herself to the other; the anther of which was not mature so soon as the former. See Sect. VIII. 8. of this work.

Dr. Peschier of Geneva thinks, he has discountenanced this idea of amatorial sensibility of vegetables by two experiments, which are related in *Journal de Physique de Lametherie*, T. II. p. 343. One of these consisted of his tying down the stigma of *epilobium angustifolium*, and yet in due time the anthers burst and shed their pollen, and thus committed a kind of vegetable Onanism; and also that he castrated the stamens of this flower, and yet the stigma opened and arose, as if the anthers had been present. The other experiment consisted in his confining a branch of barbery, *berberis*, in a glass, and subjecting the stamina of the flowers to the vapour of nitrous acid, which by this stimulus arose from their petals to the stigma, and after a few minutes again retired to their petals. Both these experiments rather seem to confirm than to enfeeble the analogy between plants and animals; as the amatorial motions of these flowers were thus produced by internal or external stimuli, as in the healthy or diseased states of animals.

Another mode, in which the prolific dust is dispersed, is by the bursting of the anther, and its consequent diffusion in air, either so as to make a cloud near the females, which exist in the same flower, or on the same plant, which is the most usual manner; or by its being carried by the winds to a greater distance, as in the flowers of the class monœcia, or one house. So in *urtica*, nettle, the male

flowers are separate from the female, and the anthers are seen in fair weather to burst with force, and to discharge their dust, which hovers about the plant like a cloud.

In plants of the class diœcia, or two houses, the fecundating farina is carried to the distance of many miles by the winds, as has been proved by the impregnation of some female date trees, which were at a great distance from the male ones. And the male flowers themselves of *vallisneria* are carried many miles down the rivers, which it inhabits, to the female ones. This plant has its roots at the bottom of the Rhone; the flowers of the female plant float on the surface of the water, and are furnished with an elastic spiral stalk, which extends or contracts, as the water rises and falls. The flowers of the male plant are produced under water, and as soon as their farina, or dust, is mature, they detach themselves from the plant, and rise to the surface, continue to flourish, and are wafted by the air, or borne by the currents, to the female flowers. In this resembling those tribes of insects, where the males at certain seasons acquire wings, but not the females, as ants, coccus, lampyris, phalæna, brumata, lichanella. See *vallisneria* in the Families of Plants, translated from Linneus. Johnson, London.

The plants, which grow in the air, are frequently injured in wet seasons by the moisture occasioning the cells of the anthers, which contain the fecundating farina, to burst, and to shed it on the ground. To which a scarcity of the quantity of wheat, or an imperfection of its fecundating quality, and the ustilago, or smut, have rationally been ascribed, as its anthers are exposed on long filaments to the weather. On this account many flowers close their corols before rain, and the aquatic plants of rivers perform their impregnations in the air. But M. Bonnet remarks another method of the dispersion of the fecundating influence of some marine plants, in which the male organ does not project a fine powder, but a liquor, which forms a perceptible cloud in the water; and adds, that the male salamander darts his

femen into the water, where it forms a whitish cloud, which is afterwards received by the swollen anus of the female, and she becomes impregnated. Nor is this vegetable impregnation in water unanalogous to other animal impregnations, as the spawn of frogs and of fish is delivered from the female before it is fecundated; and its fecundation is seen to succeed in water; and Spallanzani found, that the feminal fluid even of dogs, as well as of frogs, retained its prolific quality when diluted with much water. Bonnet's *Œuvres Philosoph.* in a letter to Spallanzani.

3. The other parts, which rise on the edge of the pericarp, and expand themselves before the impregnation of the seed, are the corol and nectaries. The former of these has been shewn to be a respiratory organ for the purpose of oxygenating the blood to a greater degree than in the green foliage, as it is there exposed to the air beneath a finer pellicle, and acquires variety of colours. See Sect. IV. 5. 1. to which may be added, that as the corol in *helleborus niger*, Christmas rose, changes after the fecundation of the seed into a calyx, losing its white colour, and becoming green. So in many flowers the calyx falls off along with the corol; in these it should be esteemed a part of or appendage to the corol; whereas those calyxes, which are permanent after the corol falls off, are properly parts of the pericarp or vegetable uterus.

4. The nectary, or honey-cup, is evidently an appendage to the corol, and is the reservoir of the honey, which is secreted by an appropriate gland from the blood after its oxygenation in the corol, as mentioned in Sect. IV. 5. 5. and is absorbed for nutriment by the sexual parts of the flower. This purpose however has as yet escaped the researches of philosophical botanists. M. Pontedera believes it designed to lubricate the vegetable uterus. (*Antholog.* p. 49.) Others have supposed, that the honey, when reabsorbed, might serve the purpose of the liquor amnii, or white of an egg, as a nutriment for the young embryo, or fecundated seed, in its early state of existence.

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But as the nectary is found equally general in male flowers as in female ones, and as the young embryo, or seed, grows before the petals and nectary are expanded, and after they fall off; these seem to be insurmountable objections to both the above-mentioned opinions.

In many tribes of insects, as the silk-worm, and perhaps in all the moths and butterflies, the male and female parents die, as soon as the eggs are impregnated and excluded, the eggs remaining to be perfected and hatched at some future time. The same thing happens to the male and female parts of flowers; the anthers and filaments, which constitute the male parts of the flower, and the stigma and style, which constitute the sensitive or amatorial organ of the female part of the flower, fall off and die, as soon as the seeds are impregnated, and along with these the petals and nectary. Now the moths and butterflies above mentioned, as soon as they acquire the passion and the apparatus for the reproduction of their species, lose the power of feeding upon leaves, as they did before, and become nourished by what?—by honey alone.

Hence we acquire a strong analogy for the use of the nectary, or secretion of honey, in the vegetable economy; which is, that the male parts of flowers, and the female parts, as soon as they leave their fetus-state, expanding their petals, (which constitute their lungs) become sensible to the passion, and gain the apparatus, for the reproduction of their species; and are fed and nourished with honey like the insects above described; and that hence the nectary begins its office of producing honey, and dies or ceases to produce honey, at the same time with the birth and death of the anthers and the stigmas; which, whether existing in the same or in different flowers, are separate and distinct animated beings.

Previous to this time the anthers with their filaments, and the stigmas with their styles, are in their fetus-state sustained in some plants by their umbilical vessels, like the unexpanded leaf-buds, as in

colchicum autumnale, and daphne mezereon; and in other plants by the bractes, or floral-leaves, as in rhubarb, which are expanded long before the opening of the flower; the seeds at the same time existing in the vegetable womb yet unimpregnated, and the dust yet unripe in the cells of the anthers. After this period the petals become expanded, which have been shewn to constitute the lungs of the flower; the umbilical vessels, which before nourished the anthers and the stigmas, coalesce, or cease to nourish them; and they acquire blood more oxygenated by the air, obtain the passion and power of reproduction, are sensible to heat, and light, and moisture, and to mechanic stimulus, and become in reality insects fed with honey; similar in every respect except that all of them yet known but the male flowers of vallisneria, continue attached to the plant, on which they are produced.

So water insects, as the gnat, and amphibious animals, as the tadpole, acquire new aerial lungs, when they leave their infant state for that of puberty. And the numerous tribes of caterpillars are fed upon the common juices of vegetables found in their leaves, till they acquire the organs of reproduction; and then they feed on honey, all I believe except the silk-worm, which in this country takes no nourishment after it becomes a butterfly. And the larva or maggot of the bee, according to the observations of Mr. Hunter, is fed with raw vegetable matter, called bee-bread, which is collected from the anthers of flowers, and laid up in cells for that purpose, till the maggot becomes a winged bee, acquires greater sensibility, and is fed with honey. Phil. Transf. 1792.

Lastly, though the filaments and style, as well as the corolla and nectary, belong to the sexual organs of vegetables; yet it is the anthers alone of the stamina, and stigmas alone of the pistilla, which possess the power, and I suppose the passion of reproduction, as appears from the mutilated filaments of many flowers, as of curcuma, of linum or flax of this country, of gratiola, and hemlock-leaved geranium,

ranium, which have half their stamina untermated by anthers, and in consequence produce no prolific farina. And secondly, from the florets, which form the rays of the flowers of the order frustraneous polygamy of the class syngenesia, as the sun-flower, which are furnished with a style only, and no stigma, and are thence barren. There is also a style without a stigma in the whole order of dioecia gynandria, the male flowers of which are thence barren, and shews the necessity of the existence of the stigma to the fecundation of the vegetable uterus, probably owing to its amatorial action in conveying the living principle to the included seeds like the fallopian tubes of the animal womb.

5. The seeds are produced in the pericarp, and at first acquire nutriment by the umbilical vessels previous to their fecundation, like the unexpanded leaf-buds; and then by the caudex down the bark with its radicles, which is oxygenated by the bractes, or floral-leaves, as soon as these are expanded, they afterwards become in one day impregnated in some flowers, as in the oenothera, cactus grandiflorus, and cistus; and the corol or petals, with the stamens and stigmas, and nectaries, wither and fall off. In other flowers many days elapse before the various cells of seeds are fecundated, and these more animated parts of sexual reproduction perish. But in all cases the seeds remain in the pericarp or uterus after-fecundation as before it, except in those plants, which are called proliferus, as the polygonum viviparum, and magical onions, which immediately begin to vegetate; in all other plants the seed either sleeps till the ensuing spring, as in the colchicum and hamamelis; or they continue to grow to maturity, and to be nourished in the pericarp by the blood of the parent flower-bud, which is oxygenated in the bractes or floral-leaves, till they become perfected like eggs, and fall on the ground, or are otherwise dispersed, for the purpose of taking root in the earth.

Whence it appears, that in the sexual reproduction of vegetables the amatorial organ is distinct from the uterus, as is probably the case
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in animals; which in female quadrupeds would seem to sleep after impregnation during the time of gestation and lactescence, and afterwards to revive; whereas this amatorial organ in vegetable flowers perishes, when the uterus is impregnated, along with the male organs, neither of which are any longer of use in these annual beings.

The various methods, which nature has employed for the dispersion of seeds, are worth the attention of the farmer and gardener, both for the purpose of preventing the growth of noxious seeds, and of collecting the profitable ones. The pericarp of some plants bursts with sudden violence, when the seed is mature, and disperses it to considerable distance; as that of wood-forrel, *oxalis acetocalla*; and of *impatiens*, touch me not. The seeds of many plants of the class *singenesia* are furnished with a plume, by which admirable mechanism they are disseminated by the winds far from their parent stem, and look like a shuttlecock, as they fly. Other seeds are disseminated by animals; of these some attach themselves to their hair or feathers by a gluten, as mistletoe; others by hooks, as *clivers*, *galium aperine*; burdock, *arctium lappa*; hound's-tongue, *cynoglossum*. Others are swallowed whole for the sake of the fruit, and voided uninjured, as the hawthorn, *cratægus*, juniper, and some grasses. And the seeds of aquatic plants, and of those which grow on the banks of rivers, are carried many miles by the currents into which they fall.

Other seeds are separated from each other, and dispersed by the twisting of the awn at the summit of them, when moistened by rain, as a black oat, *avena fatua*, with hairy awns, which seems to crawl like an insect when moistened; geranium also, and barley; and as this happens in wet weather, the moist ground is then fit to receive and nourish them. The awns of the geranium have been used as hygrometers by sticking the base of the seed into a cork for a pedestal; and marking divisions on a paper circle beneath it; and the awn of barley is furnished with stiff points, which, like the teeth of a saw, are all turned towards one end of it; as this long awn lies upon the ground,

it extends itself in the moist air of night, and pushes forward the barley-corn, which it adheres to; in the day it shortens as it dries; and as these points prevent it from receding, it draws up its pointed end; and thus, creeping like a worm, will travel many feet from the parent stem; and may thus be used as a travelling hygrometer, when laid on a cloth on the floor, like the automaton of Mr. Edgeworth, described in Botanic Garden, article *Impatiens*, Vol. II.

6. The formation of the organs for sexual generation, in contradistinction to those for lateral generation, in vegetables, and in some animals, as the polypus, the tænia, and the volvox, seems the chef d'œuvre, the master-piece of nature, as appears from many flying insects, as moths and butterflies, which seem to undergo a general change of their forms solely for the purpose of sexual reproduction; and in all other animals these organs are not complete till the maturity of the creature; whereas the lateral generation commences with the infancy of the germ or bud, as on the roots of young herbs, and on the stems of infant trees.

There seems nevertheless to be one circumstance, in which the solitary generation of the buds of plants, when the plants are at their maturity, is superior to the sexual generation by seeds. This consists in the progeny of the former being more perfect than that of the latter; in respect to the power of the reproduction of their species. Thus in many plants, as in tulips and apple-trees, the young vegetable from the seed produces other bulbs, or buds, for some years, which seem annually to improve, till at length they acquire a puberty, if it may be so called, and become furnished with sexual organs for the purpose of feminal reproduction; whereas the leaf-buds, or leaf-bulbs, of the apple-tree and tulip during their first years produce other leaf-buds; or leaf-bulbs, rather more perfect than their parents; and when these bulbs, and buds, arrive at their puberty, or maturity, so as to be capable of sexual generation, their new bulbs and new buds also, if taken from their dying parents, and transplanted or ingrafted, or left

adhering to them, are immediately capable of producing flowers, and a consequent feminal progeny.

As the progeny by lateral generation so exactly resembles the parent stock, it follows, that though any new variety, or improvement, may be thus continued for a century or two, as in grafted fruit-trees, yet that no new variety or improvement can be obtained by this mode of generation; though some hereditary diseases, as the canker, are believed to arise in ingrafted trees, which have long been propagated by lateral generation, as explained in No. 1. 3. of this Section.

But from the sexual, or amatorial, generation of plants new varieties, or improvements, are frequently obtained; as many of the young plants from seeds are dissimilar to the parent, and some of them superior to the parent in the qualities we wish to possess; which is another proof that the anthers and stigmas of plants are animated beings, different from the green foliage of the tree on which they grow; as they produce varieties in the form of their offspring like sexual animals, which buds do not.

Besides the production of different, and sometimes more excellent, varieties in the species of vegetables from seeds, another advantage occurs from sexual generation, which is the production of new species of plants, or mules, by shedding the fecundating dust of some flowers on the stigmas of others of a different species, though generally of the same genus.

A mule cabbage is described in the Bath Agriculture, Vol. I. Art. 4, which is said to fatten a beast six weeks sooner than turneps. It is there said, “ that the sort of cabbage principally raised is the tallow-loaf or drum-head cabbage; but it being too tender to bear sharp frost, I planted some of this sort and the common purple-cabbage used for pickling, (it being the hardiest I am acquainted with) alternately; and when the seed-pods were perfectly formed, I cut down the purple, and left the other for seed. This had the desired effect, and produced a mixt stock of a deep green colour with purple

veins, retaining the size of the drum head, and acquiring the hardness of the purple."

In another curious paper of the Bath Society, Vol. V. p. 38, Mr. Wimpey relates, that he planted a field with garden-beans in rows about three feet asunder in the following order, mazagan, white-blossom, long-podded, Sandwich-toker, and Windfor-beans. The mazagan and white-blossom were thrashed first, when to his great surprise he found many new species of beans; those from the mazagan were mottled black and white; the white-blossoms were brown and yellow instead of their natural black; and they were both much larger than usual. See Sect. XVI. 4. of this work.

There is an apple described in Bradley's work, which is said to have one side of it a sweet fruit, which boils soft, and the other side a sour fruit, which boils hard. This Mr. Bradley so long ago as the year 1721 ingeniously ascribes to the farina of one of these apples impregnating the other; which would seem the more probable, if we consider, that each division of an apple is a separate womb, and may therefore have a separate impregnation, like puppies of different kinds in one litter. The same is said to have occurred in oranges and lemons, and grapes of different colours.

Vegetable mules are said to be numerous, and, like the mules of the animal kingdom, not always to continue their species by feed. There is an account of a curious mule from the *antirrhinum linaria*, toad-flax, in the *Amœnit. Academ.* V. I. No. 3. and many hybrid plants are described in No. 32. The *urtica alienata* is an evergreen plant, which appears to be a nettle from the male flowers, and a pelitory (*parietaria*) from the female ones and the fruit, and is hence between both. Murray, *Syst. Veg.* Amongst the English indigenous plants, the *veronica hybryda*, mule speedwell, is supposed to have originated from the officinal one, and the spiked one; and the *Sibthorpia Europæa* to have for its parents the golden faxifrage and marsh pennywort. Pulteney's View of Linneus, p. 253.

There

There is another vegetable fact published by M. Koelruter, which he calls "a complete metamorphosis of one natural species of plants into another;" which shews, that in seeds as well as in buds, the embryo proceeds from the male parent, though the form of the subsequent mature plant is in part dependent on the female. M. Koelruter impregnated a stigma of the *nicotiana rustica* with the farina of the *nicotiana paniculata*, and obtained prolific seeds from it. With the plants, which sprung from these seeds, he repeated the experiment, impregnating their pistilla with the farina of the *nicotiana paniculata*. As the mule plants, which he thus produced, were prolific, he continued to impregnate them for many generations with the farina of the *nicotiana paniculata*, and they became more and more like the male parent, till he at length obtained six plants in every respect perfectly similar to the *nicotiana paniculata*, and in no respect resembling their female parent the *nicotiana rustica*. Blumenback on Generation.

Mr. Graberg, Mr. Schreber, and Mr. Ramstrom, seem of opinion, that the internal structure or parts of fructification in mule plants resemble the female parent; but that the habit or external structure resembles the male parent. See treatises under the above names in Vol. VI. Amœnit. Academic.

7. Something similar to this seems to obtain in mixing the breeds of the same species of animals, and in animal mules, which may be worth the attention of the grazier. The mule produced from a horse and a she ass resembles the horse externally with his ears, mane, and tail; but with the nature, or manners of an ass. But the hinnus, or creature produced from a male ass and a mare, resembles the father externally in stature, ash-colour, and the black cross on his shoulders, but with the nature or manners of a horse. The breed from Spanish rams and Swedish ewes resembled the Spanish sheep in wool, stature, and external form; but was as hardy as the Swedish sheep; and the contrary occurred in the breeds which were produced from Swedish rams

rams and Spanish ewes. The offspring from the male goat of Angora and the Swedish female goat had long soft camel's hair; but that from the male Swedish goat, and the female one of Angora, had no improvement of their wool. An English ram without horns, and a Swedish horned ewe, produced sheep without horns. Amœn. Acad. Vol. VI. p. 13.

8. From these circumstances it appears, that not only new varieties may be procured from the seminal offspring of plants; where those from the lateral offspring become diseased by age, as the cankered apple-grafts, and perhaps the curled potatoes, and barren strawberries; but that more curious or useful fruits or flowers may be obtained by shedding the farina of some valuable plant on the stigma of another variety of the same species, as of two different but equally excellent apple-trees, or tulip-flowers, hyacinths, anemonies, and geraniums. And thirdly, that mules may be produced by a mixture of different species of plants, and perhaps of different genera; as of pines and melons; grapes and gooseberries; oranges and apples; apricots and nectarines; nuts and acorns; which may be afterwards propagated by the lateral progeny, if not by the seminal one.

The facility of generating vegetable mules seems forcibly to have struck the great Linneus; who in the preface to his natural orders of plants at the end of his *Genera Plantarum* thinks, that about sixty vegetables were at first created corresponding with his natural orders. That a mixture of these orders amongst themselves produced the genera; that a mixture of the genera amongst themselves produced the species; and that a mixture of the species produced the varieties, which he believes to accord with the general progress of nature "*from simpler things to the more compound.*"

In the same manner it may be supposed, that many of the present species of animals were originally mules produced by a mixture of animals of different genera; and that all such mules, as had perfect organs of reproduction, continued their species. But as these organs seem

seem to be the chef d'œuvre of nature, as above remarked, they often become imperfect in the generation of mules, and the species then becomes extinct ; as it could not be propagated by sexual generation, it is possible, that many new kinds of mules, which might be useful for labour, or by their milk or wool, or for food, might still be produced by the method of Spallanzani ; who diluted the seminal fluid of a dog with much warm water, and by injecting it fecundated a bitch, and produced puppies like the dog.

Thus new animal combinations might possibly be generated numerous as the fabled monsters of antiquity ; as between the ram and the female goat ; the stag and the cow ; the horse and the doe ; the bull and the mare ; boar and bitch ; dog and sow. And secondly, as Spallanzani diluted the seminal fluid of a male frog with water, and fecundated some female spawn with it, and produced perfect tadpoles, there is reason to conclude, that new combinations of fish might thus be generated, and people our rivers with aquatic monsters. And lastly, that it is not impossible, as some philosopher has already supposed, if Spallanzani should continue his experiments, that some beautiful productions might be generated between the vegetable and animal kingdoms, like the eastern fable of the rose and nightingale, and which might be propagated by lateral or paternal, though not by sexual or seminal generation.

The classic reader will here be reminded of the metamorphoses of Ovid, of gods turned into bulls and swans, men into frogs and partridges, ladies into trees and flowers, of sphinxes, griffins, dragons, mermaids, centaurs, and minotaurs ; Pasiphae and her bull ; Leda and her swan ; Arethusa and her fish-god Alpheus, and conclude that mules in early times were more frequent than at present, which occasioned the poets and the priests of antiquity to invent so many fabulous monsters, and impose them on the credulity of mankind.

III. VEGETABLE GENERATION.

1. The intelligent reader is become, I hope, by this time so much interested in the further investigation of the circumstances attending the lateral and sexual generation of vegetables, that he will not be displeased with the continuance of the subject for a few more pages, so agreeable from its novelty, and so important from its future application to animal reproduction.

If a scion of a nonpareil apple be ingrafted on a crab-stock, and a golden pippin be ingrafted on the nonpareil, what happens? The caudex of the bud of the golden pippin consists of its proper absorbent vessels, arteries, and veins, till it reaches down to the nonpareil-stock; and then the continuation of its caudex downwards consists of vessels similar to those of the nonpareil; when its caudex descends still lower, it consists of vessels similar to those of the crab-stock.

The truth of this is shewn by two circumstances; first, because the lower parts of this compound tree will occasionally put forth buds similar to the original stock. And secondly, because in some ingrafted trees, where a quick-growing scion has been inserted into a stock of slower growth, as is often seen in old cherry-trees, the upper part of the trunk of the tree has become of almost double the diameter of the lower part; both which occurrences shew, that the lower part of the trunk of the tree continues to be of the same kind, though it must have been so repeatedly covered over with new circles of wood, bark, and cuticle.

Now as the caudex of each bud, which passes the whole length of the trunk of the tree, and forms a communication from the upper part, or plumula, to the lower part, or radicle, must consist in these doubly ingrafted trees of three different kinds of caudexes, resembling those of the different stocks or scions; we acquire a knowledge of what may be termed a lateral or paternal mule, in contradistinction

to a sexual mule. For as in these trees thus combined by ingraftment every bud has the upper parts of its caudex that of a golden pippin, the middle part of it that of a nonpareil, of the lower part of it that of a crab; if these caudexes, which constitute the filaments of the bark, could be separated intire from the tree with their plumules and radicles, they would exhibit so many lateral or paternal mules, consisting of the connected parts of their three parents; the plumula belonging to the upper parent, and the radicle to the lower one, and the triple caudex to them all.

A separation of these buds from the parent plant is said to have been observed by Mr. Blumenback in the *conferva fontinalis*, a vegetable which consists of small short slender threads, which grow in our fountains, and fix their roots in the mud. He observed by magnifying glasses, that the extremities of the threads swell, and from small tubera, or heads, which gradually separate from the parent threads, attach themselves to the ground, and become perfect vegetables; the whole progress of their formation can be observed in forty-eight hours. *Observations on Plants, by Von Uslar, Creech, Edinb.*

2. The lateral propagation of the polypus found in our ditches in July, but more particularly that of the *hydra stentorea*, is wonderfully analagous to the above idea of the lateral generation of vegetables. The *hydra stentorea*, according to the account of monsieur Trembley, multiplies itself by splitting lengthwise; and in twenty-four hours these divisions, which adhere to a common pedicle, resplit, and form four distinct animals. These four in an equal time split again, and thus double their number daily, till they acquire a figure somewhat resembling a nosegay. The young animals afterwards separate from the parent, attach themselves to aquatic plants, and give rise to new colonies.

Another curious animal fact is related by Blumenback in his treatise on generation, concerning the fresh water polypus. He cut two of them in half, which were of different colours, and applying the upper

part of one to the lower part of the other, by means of a glass-tube, and retaining them thus for some time in contact with each other, the two divided extremities united, and became one animal.

The attentive reader has already anticipated me in applying these wonderful modes of lateral animal reproduction and conjunction to the lateral propagation and ingraftment of vegetables. The junction of the head-part of one polypus to the tail-part of another is exactly represented by the ingraftment of a scion on the stock of another tree. The plumula, or apex of each bud, with the upper part of its caudex, joins to the long caudex of the stock, which passing down the trunk terminates in the radicles of it. And if this compound vegetable could be separated longitudinally from the other long filaments of the bark in its vicinity, like the fibres of the bark of the mulberry-tree prepared at Otaheite, or as the bark of hemp and flax are prepared in this country, as the young ones of the hydra stentorea separate from their parents, it might claim the name of a lateral or paternal mule, as above mentioned.

3. It hence appears, that every new bud of a tree, where two scions have been inserted over each other on a stock, if it could be separated from the plume to the radicle, must consist of three different kinds of caudex, and might therefore be called a triple lateral mule. And that hence it follows, that every part of this new triple caudex, must have been separated or secreted laterally from the adjoining part of the trunk of the tree; and that it could not be formed, as I formerly believed, from the roots of the plume of the bud descending from the upper part of the caudex of it to the earth. A circumstance of great importance in the investigation of the curious subject of the lateral generation of vegetables, and of insects.

One might hence suspect, that if Blumenback had attended to the propagation of the polypus, which he had composed of two half polypi, that the young progeny might have possessed two colours resembling

sembling the compound parent, like the different caudexes of ingrafted trees; an experiment well worthy repeated observation.

4. Another animal fact ought also to be here mentioned, that many insects, as common earth-worms as well as the polypus, are said to possess so much life throughout a great part of their system, that they may be cut into two or more pieces without destroying them, as each piece will acquire a new head, or a new tail, or both; and the insect will thus become multiplied. How exactly this is resembled by the long caudex of the buds of trees, which possess such vegetable life from one extremity to the other, that when the head or plume is lopped off, it can produce a new plume; and when the lower part is cut off, it can produce new radicles; and may be thus wonderfully multiplied.

5. Hence we acquire some new and important ideas concerning the lateral generation of vegetables, and which may probably contribute to elucidate their sexual generation. These are, first, that the parts of the long caudex of each new bud of an ingrafted tree, and consequently of all trees, are separated or secreted from the correspondent or adjoining parts of the long caudex of the last year's bud, which was its parent; and not that it consists of the roots of each new bud shot down from the plumula or apex of it, as I formerly supposed; and that those various molecules, or fibrils, secreted from the caudex of the last year's buds, adjoin and grow together beneath the cuticle of the trunk of the tree, the upper ones forming the plumula of the new bud, which is its leaf or lungs, to acquire oxygen from the atmosphere; and the lower ones forming the radicles of it, which are absorbent vessels to acquire nutriment from the earth.

Secondly, that every part of the caudex of an ingrafted tree, and consequently of all trees, can generate or produce a new bud, when the upper part of it is strangulated with a wire or cut off, or otherwise when it is supplied more abundantly with nutriment, ventilation, and light. And that each of these new buds thus produced

resembles that part of the flock in compound trees, where it arises. Thus in the triple tree above mentioned a bud from the upper part of the long caudexes, which form the filaments of the bark, would become a golden pippin branch ; a bud from the middle part of them would become a nonpareil branch ; and a bud from the lower part a crab branch.

Thirdly, another wonderful property of this lateral mule progeny of trees compounded by ingraftment consists in this, that the new mule may consist of parts from three, or four, or many parents, when so many different scions are ingrafted on each other ; whence a question may arise, whether a mixture of two kinds of anther-dust previous to its application to the stigma of flowers might not produce a threefold mule, partaking of the likeness of both the males ?

6. On this nice subject of reproduction so far removed from common apprehension the patient reader will excuse a more prolix investigation. The attraction of all matter to the centres of the planets, or of the sun, is termed gravitation ; that of particular bodies to each other is generally called chemical affinity ; to which the attractions belonging to electricity and magnetism appear to be allied.

In these latter kinds of attraction two circumstances seem to be required ; first, the power to attract possessed by one of the bodies, and secondly, the aptitude to be attracted possessed by the other. Thus when a magnet attracts iron, it may be said to possess a specific tendency to unite with the iron ; and the iron may be said to possess a specific aptitude to be united with the magnet. The former appears to reside in the magnet, because it can be deprived of its attractive power, which can also be restored to it ; and the iron appears to possess a specific aptitude to be united with the magnet, because no other metal will approach it. In the same manner a rubbed stick of sealing-wax may be said to possess a specific tendency to unite with a light straw, but not with a glass bead. Here the straw seems to possess a specific aptitude to unite with the rubbed sealing-wax, because
many

many other bodies refuse to do so, as glafs, silk, air; and lastly, the specific attraction of the rubbed sealing-wax can be withdrawn or restored; to which may be added, that some chemical combinations may arise from the single attraction of one body, and the aptitude to be attracted of another; or they may be owing to reciprocal attractions of the two bodies, as in what is termed by the chemists double-affinity, which is known to be so powerful as to separate those bodies, which are held together by the single attraction probably of one of them to the other, which other possesses only an aptitude to be attracted by the former.

7. The above account of the tendencies to union by unorganized or inanimate matter is not given as a philosophical analogy, but to facilitate our conception of the adjunctions or concretions observable in organized or animated bodies, which constitute their formation, their nutrition, and their growth. These may be divided into two kinds; first the junction or union of animated bodies with inanimate matter, as when fruit or flesh is swallowed into the stomach, and becomes absorbed by the lacteals; and the second, where living particles coalesce or concrete together, as in the formation, nutrition, or conjunction of the parts of living animals.

In respect to the former, the animal parts, as the nostrils and palate, possess an appetency, when stimulated by the scent and flavour of agreeable food, to unite themselves with it; and the inanimate material possesses an aptitude to be thus united with the animal organ. The same occurs when the food is swallowed into the stomach; the mouths of the lacteal vessels being agreeably stimulated possess an appetency to absorb the particles of the digesting mass, which is in a situation of undergoing chemical changes, and possesses at some period of them an aptitude to be united with the mouths of the absorbent lacteals.

But when these absorbed particles of inanimate matter have been circulated in the blood, they seem gradually to obtain a kind of vitality;

tality; whence Mr. John Hunter, and I believe some ancient philosophers, and the divine Moses, asserted, that the blood is alive; that is, that it possesses some degree of organization, or other properties different from those of inanimate matter, which are not producible by any chemical process, and which cease to exist along with the life of the animal. Hence for the purpose of nutrition there is reason to suspect, that two circumstances are necessary, both dependent upon life, and consequent activity; these are first an appetency of the fibrils of the fixed organization, which wants nutrition; and secondly, a propensity of the fluid molecules existing in the blood, or secreted from it, to unite with the organ now stimulated into action. So that nutrition may be said to be affected by the embrace or cohesion of the fibrils, which possess nutritive appetencies, with the molecules, which possess nutritive propensities.

8. If the philosopher, who thinks on this subject, should not be inclined to believe that the whole of the blood is alive; he can not easily deny life to that part of it which is secreted by the organs of generation, and conveys vitality to the new embryo, which it produces. Hence though in the process of nutrition the activity of two kinds of fibrils or molecules may be suspected, yet in the process of the generation of a new vegetable or animal, there seems great reason to believe, that both the combining and combined particles are endued with vitality; that is, with some degree of organization or other properties not existing in inanimate matter, which we beg leave to denominate fibrils with formative appetencies, and molecules with formative propensities, as the former may seem to possess a greater degree of organization than the latter.

And thus it appears, that though nutrition may be conceived to be produced by the animated fibrils of an organized part being stimulated into action by inanimate molecules, which they then embrace, and may thus be popularly compared to the simple attractions of chemistry; yet that in the production of a new embryo, whether

ther vegetable or animal, both the fibrils with formative appetencies, and the molecules with formative propensities, reciprocally stimulate and embrace each other, and instantly coalesce, and may thus popularly be compared to the double affinities of chemistry. But there are animal facts, which resemble both these, and are thence more philosophically analogous to them; and these are the two great supports of animated nature, the passions of hunger and of love. In the former the appetency resides only in the stomach, or perhaps in the cardia ventriculi, but the object consists of inanimate matter; in the latter reciprocal appetencies and propensities exist in the male and female, which mutually excite them to embrace each other. Two other animal facts are equally analogous; the thirst, which resides at the upper end of the esophagus, and though it possesses appetency itself, its object is inanimate matter; but in lactescent females, when they give suck to their young, there exists a reciprocal appetency in the mother to part with her milk, and in the young offspring to receive it.

This then finally I conceive to be the manner of the production of the lateral progeny of vegetables. The long caudex of an existing bud of a tree, which constitutes a single filament of the present bark, is furnished with glands numerous as the perspirative or mucous glands of animal bodies; and that these are of two kinds, the one secreting from the vegetable blood the fibrils with formative appetencies, correspondent to the masculine secretion of animals; and the other secreting from the vegetable blood the molecules with formative propensities, correspondent to the feminine secretion of animals; and then that both these kinds of formative particles are deposited beneath the cuticle of the bark along the whole course of it, and nearly at the same time by the sympathy of the secreting organs, and instantly embrace and coalesce, forming a new caudex along the side of its parent with vegetable life, and with the additional powers of nutrition, and of growth.

9. This then is the great secret of nature ; more living particles are produced by the powers of vitality in the fabrication of the vegetable blood, than are necessary for nutrition or restoration of decomposing organs. These are secreted, and detrued externally, and produce by their combination a new vital organization beneath the cuticles of trees over the old one. These new combinations of vital fibrils and molecules acquire new appetencies, or fabricate molecules with new propensities, and thus possess the power of forming the leaf or lungs at one extremity of the new caudex ; and the radicles, or absorbent vessels at the other end ; and some of them, as in the central buds which terminate the branches, finally form the sexual organs of reproduction, which constitute the flower.

That new organizations of the growing system acquire new appetencies appears from the production of the passion for generation, as soon as the adapted organs are complete ; and from the desire of lactescent females to suckle their offspring, and also from the variation of the palate, or desire for particular kinds of food, as we advance in life, as from milk to flesh. Thus as a popular allusion, and not as a philosophical analogy, we may again be allowed to apply to the combinations of chemistry ; where two different kinds of particles unite, as acids and alkalies, a third something is produced, which possesses attractions dissimilar to those of either of them ; and that new organizations form new molecules appears from the secretions of the seminal and uterine glands, when they have acquired their maturity ; and from the breasts of lactescent females.

10. In the lateral propagation of vegetable buds as the superfluous fibrils or molecules, which were fabricated in the blood, or detached from living organs, and possess nutritive or formative appetencies and propensities, and which were more abundant than were required for the nutrition of the parent vegetable bud, when it had obtained its full growth, were secreted by innumerable glands on the various parts of its surface beneath the general cuticle of the tree, and there embracing

bracing and coalescing, form a new embryo caudex, which gradually produces a new plumula and radicles. And as the different parts of the new caudex of a compound tree resemble the parts of the parent caudex, to which it adheres, it was shewn, beyond all doubt, that different fibrils or molecules were detached from different parts of the parent caudex to form the filial one.

So in the sexual propagation of vegetables the superfluous living fibrils, or molecules, floating in the blood, appear to be secreted from it by two kinds of glands only; those which constitute the anthers, and those which constitute the pericarp of flowers. By the former I suppose the fibrils, with formative appetencies and with nutritive appetencies, to be secreted; and by the latter the molecules, with formative and with nutritive propensities. Afterwards that these fibrils with formative and nutritive appetencies, become mixed in the pericarp or uterus of the flower, with the correspondent molecules with formative and nutritive propensities; and that a new embryo is instantly produced by their reciprocal embrace and coalescence. And that parts of this new organization afterwards acquire new appetencies, and form molecules with new propensities, and thus gradually produce other parts of the growing seed, which do not at first appear, as the plumula, radicles, cuticle, and the glands of reproduction in the pericarp and anthers, which correspond in the animal fetus to the lungs, intestines, cuticle, and the organs, which distinguish the sexes.

11. From this new doctrine of a threefold vegetable mule by lateral propagation, as the new bud on the summit of a tree, which has had two scions ingrafted on it one above another, in which it is incontestibly shewn, that different fibrils, or molecules, are detached from different parts of the parent caudex to form the filial one, which adheres to it; and that it then acquires the power of producing new radicles, or a new plumula; we may safely conclude, as it is deducible from the strongest analogy, that in the production of sexual

mules, whether vegetable or animal, some parts of the new embryo were produced by, or detached from, similar parts of the parent, which they resemble. And that as these fibrils, or molecules, floated in the circulating blood of their parents, they were collected separately by appropriated glands of the male or female; and that finally, on their mixture in the matrix the new embryo was immediately generated, resembling in some parts the form of the father, and in other parts the form of the mother, according to the quantity or activity of the fibrils or molecules at the time of their conjunction.

And lastly, that various parts of the new organizations afterwards acquired new appetencies, and formed molecules with new propensities, and thus gradually produced other parts of the growing fetus, as the skin, nails, hair, and the organs which distinguish the sexes.

If the molecules secreted by the female organ into the pericarp of flowers, or into the ovary of animals, were supposed to consist of only unorganized or inanimate particles; and the fibrils secreted by the male organ only to possess formative appetencies to select and combine with them; the new embryo must probably have always resembled the father, and no mules could have had existence.

But by the theory above delivered it appears, that the new offspring, both in vegetable and animal reproduction, whether it be a mule or not, must sometimes more resemble the male parent, and sometimes the female one, and sometimes appear to be a combination of them both, as the epigram of Martial:

*Dum dubitat natura gravis puerum faceretne puellam,
Factus es, O pulcher, pene puella, puer.*

12. The certain proof above given, that some parts of the triple caudex of the new bud of a tree, which has been compounded by ingraftment, are formed from similar parts of the triple caudex of the parent bud, carries us one step further back into the mysterious process

cesses of reproduction, and somewhat countenances the ingenious conjectures of monsieur Buffon. And the analogy here observed, that as in chemical union there must be some particles of inanimate matter with attractions, and others with aptitudes to be attracted; so in the conjunctions of animated particles in the nutrition or formation of organized beings, there must exist fibrils or molecules with formative or nutritive appetencies, and others with formative or nutritive aptitudes or propensities, one of which may be secreted by the male, and the other by the female parent, may facilitate our reasoning upon this dark subject, which will be resumed and enlarged upon in the next edition of *Zoonomia*, in the section on generation.

S E C T. VIII.

I. THE MUSCLES, NERVES, AND BRAIN OF VEGETABLES.

1. *Vegetable muscles evinced by their closing their corols, and calyxes, and moving their leaves in consequence of stimulus. Hence also vegetable nerves both of sense and motion. When one part of a leaf of mimosa is touched the whole leaf falls. Hence also a vegetable brain or common sensorium.* 2. *Their irritability shewn by the absorption, and circulation of their fluids By electric shocks. By the ascent of sap-juice.* 3. *Their sensibility shewn by the collaps of mimosa. By closing their petals from defect of stimulus, as in darkness and cold. By the males and females bending to each other.* 4. *Their volition shewn from bedysarum gyrans. From polymorpha marchantia. From tendrils of vines. From their sleep.* 5. *Their associations of motion shewn by their closing their petals, performing absorption and circulation of fluids. Their acquired habits. Grains and roots from the south vegetate sooner. Apple-trees. Sensitive plant. Berberry.* 6. *Vegetables possess a sense of heat, of light, and of moisture, and consequently possess a brain or common sensorium.* 7. *They possess a sense of touch and a common sensorium.* 8. *How do the anthers and stigmas find each other? by a sense of smell. Adultery of collinsonia.* 9. *From their absorptions, secretions, senses, love and sleep, they must possess a brain. Does this reside in the pith of each individual bud?*

I. THE various motions of peculiar parts of vegetables evince the existence of muscles and nerves in those parts, such as the closing of their petals, and calyxes, at the approach of night, or in cold or wet weather; though the fibres and nerves, which constitute these muscles, are too fine for anatomical demonstration.

Some vegetables fold the older leaves over the new buds at the extremity of their stalks during the night, as alsine, chickweed; others, as the mimosa, sensitive plant, fold the upper or polished sides of their

their leaves together during their sleep. The *hedyfarum gyrans* whirls its leaves in various directions, when the air is still, by an apparently voluntary effort, probably for the purpose of respiration. The *dionœa muscipula*, Venus's fly-trap, closes its leaves from the stimulus of insects, which crawl upon them, and pierces them with its prickles. And the *apocynum androsæmifolium* contracts its petals or nectaries round the proboscis of the flies, which stimulate it, and holds them till they die, or till the sleep of the plant releases them by the relaxation of its muscular action.

From these circumstances it appears, that there are not only muscles about the moving foot-stalks or claws of the leaves and petals above mentioned; but that these muscles must be endued with nerves of sense as well as of motion. Now, as when one part of a leaf of *mimosa* is touched, the whole leaf falls, it follows, that there must be a common sensorium, or brain, where the nerves communicate, belonging to this one leaf-bud. To evince this further another leaflet was slit with sharp scissars, and some seconds of time elapsed, before the plant seemed sensible of the injury; and then the whole plant collapsed as far as the principal stem. Afterwards a small drop of oil of vitriol was put on the bud in the bosom of a leaf of another sensitive plant; and, after about half a minute, when the brain of this bud could be supposed to be destroyed, the whole leaf fell, and rose no more. If the individual buds of plants possess muscles and nerves with a brain, or common sensorium; the following questions consequently occur, and should be answered in the affirmative. Have vegetable buds irritability? have they sensation? have they volition? have they associations of motion? I am persuaded they possess them all, though in a much inferior degree even than the cold blooded animals.

2. The irritability of vegetable fibres is demonstrated by the absorption and circulation of their fluids in their roots, leaves, and petals; which can not be explained by any mechanic law, and exactly corresponds

corresponds with the absorption of the aliment, and the circulation of the blood in animals; which Physiologists have demonstrated to depend on the muscular motions of the vessels themselves, which possess irritability, and are excited into action by the stimulus of the fluids, which they acquire or contain.

The irritability of vegetable vessels is shewn by a curious experiment of Von Ufflar, who passed strong electric shocks through a plant of euphorbia, so as to destroy the life of the plant; and he then observed on cutting off a branch, that it did not bleed; though a similar branch cut off before the death of the plant effused much milky juice; whence he justly concludes, that the electric percussion had destroyed the irritability of the plant.

Mr. Cavallo asserts in his Treatise on Electricity, that he found by repeated experiments, that the plant balsam (impatiens) was destroyed by less quantities of electricity than any other vegetables, which he subjected to it; and that on examining the plant afterwards no injury on the external or internal parts of it could be discovered; whence it may be concluded that the irritability simply, and not the organization of the plant, was destroyed by the unnatural quantity of stimulus. He adds, that not only shocks from so small a coated surface as six or eight square inches, but even strong sparks from a large conductor destroyed these plants, which sometimes recovered in a day or two, but not frequently. See Sect. XIII. 3. and Sect. XIV. 2. 3. of this work.

The ascent of the sap-juice during the vernal months in the experiments both of Hales and Walker, being retarded or quite stopped during the cold parts of the day, and in the night; and on the north side of the tree in cool days, when it continued to flow on the south side, can only be ascribed to the irritability of the vegetable vessels being decreased by the deficient stimulus of heat. See this subject further treated of in Sect. XIV. 1. 10. of this work.

3. The sensibility of fibres is distinguished from their irritability by

by the pain or pleasure, which precedes or attends any animal action; and therefore supposes the existence of a common sensorium; now when one division of a leaf of *mimosa* is injured by a wound or touch, in a short time the whole leaf closes, which is owing to the actions of the distant muscles about the footstalks of the subdivisions of the leaf. Does not this prove, that there is a brain or common sensorium, where the nerves communicate in some part of this bud or leaf, as the injury of one distant part of it thus affects the whole? or in other words, that the disagreeable sensation is propagated from a part to the whole, and causes the actions of some distant muscles, in the same manner as I draw away my hand when my finger is hurt?

There are muscles placed about the foot-stalks of the leaves or leaflets of many plants, for the purpose of closing their upper surfaces together, or of bending them down so as to shoot off the showers or dew-drops, as in sensitive plant, *mimosa*; kidney-bean, *phaseolus*; and many trees. The claws of the petals, or of the divisions of the calyx of many flowers, are furnished in a similar manner with muscles, which are exerted to open or close the corol and calyx of the flower, as in *tragopogon*, *anemone*. This action of opening and closing the leaves or flowers does not appear to be produced simply by irritation on the muscles themselves, but by the connexion of those muscles with a sensitive sensorium, or brain, existing in each individual bud or flower. 1st. Because many flowers close from defect of stimulus, not by the excess of it, as by darkness, which is the absence of the stimulus of light; or by cold, which is the absence of the stimulus of heat. Now the defect of heat, like the absence of food, or of drink, affects our senses with pain, which had been previously accustomed to a greater quantity of them, and a cutaneous shivering may be excited in consequence of the pain; but a muscle cannot be said to be stimulated into action by a defect of stimulus, though some modern writers on medicine have called cold a stimulus to animal fibres, which it always renders torpid or inactive; a theory

derived from Galen, and which must have originated in his total ignorance of chemistry and natural philosophy.

In some flowers the males bend into contact with the females, as in *cistus*, *kalmia*, *fritillaria perfoliata*, *lithrum falicaria*; in others the female bends to the males, as in *collinsonia*, *gloriosa*, *genista*, *epilobium*; which shews a sensibility to the passion of reproduction. In *irritation* the stimulated muscles only are brought into action, without being perceived by the other parts of the system; but in *sensation* the whole system is affected by means of the brain or common sensorium, and thence very distant muscles are brought into action to acquire an agreeable object, or to repel or withdraw from a disagreeable one. See *Zoonomia*, Vol. I. Sect. XIII. 2.

4. That plants possess in some degree the power of volition would appear first from the *hedyfarum gyrans*, which moves its leaves in circular directions when the air is too still. Secondly, from the *marchantia polymorpha*, in which some yellow wool advances from the flower-bearing anthers, while it drops its dust like atoms. Murray's System of Vegetables. Thirdly, from the tendrils of vines, and the stems of other climbing vegetables, which continue to move round, till they find something to adhere to, or till they have rolled themselves up in a spiral line like a cork-screw. And lastly, from the efforts of almost all plants to turn the upper surface of their leaves, or their flowers, to the light.

But there is an indubitable proof of plants possessing some degree of voluntariness, and that is deduced from their sleep. In animal bodies sleep consists in a suspension or temporary abolition of voluntary power; the organs of sense being at the same time closed, or by some other means rendered unfit for the perception of external bodies. Now the sleep of plants is proved by the hanging down or closing of the leaves of many plants, and of shutting the petals and calyxes of many flowers in the dark, and their again opening or expanding them in the light, or at certain hours of the day.

5. In respect to vegetables acquiring affociations of motion, or habits of action, the former is seen in the absorptions and circulations of their fluids, and in the various movements above described ; which whirl their leaves or tendrils, and close or open their corols and calyxes, which could not be performed without the synchronous and associated actions of many muscles ; as in the absorptions and circulations of animal bodies, and the movements of their limbs.

Other acquired habits of vegetable actions appear from the grains and roots brought from more southern latitudes, which germinate here sooner than those which are brought from more northern ones, owing to their acquired habits. Fordyce on Agriculture. And from the apple trees sent from hence to New York, which blossomed for a few years too early for the climate, and bore no fruit ; but afterwards learnt to accommodate themselves to their new situation. Travels in New York by Professor Kalm.

The divisions of the leaves of the sensitive plant have been accustomed to contract at the same time from the absence of light ; hence if by any other circumstance, as a slight stroke or injury, one division is irritated into contraction ; the neighbouring ones contract also, from their motions being associated with those of the irritated part. So the various stamina of the barberry have been accustomed to contract together in the evening ; and thence, if you stimulate one of them with a pin, according to the experiment of Dr. Smith, they all contract from their acquired affociations.

6. This leads us to a curious inquiry, whether vegetables possess any organs of sense ? Certain it is, that they possess a sense of heat and cold, another of moisture and dryness, and another of light and darkness ; for they close their petals occasionally from the presence of cold, moisture, or darkness. And it has been already shewn, that these actions cannot be performed simply from irritation, because cold and darkness are defective quantities of our usual stimuli ; and that on that account sensation or volition are employed ; and in conse-

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quence a sensorium or union of the nerves must exist. So when we go into the light, we contract the iris, not from any stimulus of the light on the fine muscles of the iris, but from its motions being associated with the sensation of too much light on the retina, which could not take place without a sensorium or center of union of the nerves of the iris with those of vision.

7. Besides these organs of sense, which distinguish cold, moisture, and darkness, the leaves of mimosa, and of dionæa, and of drosera, and the stamens of many flowers, as of the barberry, and of the numerous class of syngenesia, are sensible to mechanic impact; that is, they possess a sense of touch; and as many of their distant muscles are in consequence excited into action, this also evinces, that they possess a common sensorium, by which this sensation is communicated to the whole, and volition occasionally exerted.

8. Lastly, in many flowers the anthers when mature approach the stigma, in others the female organ approaches to the male. I ask, by what means are the anthers in many flowers, and stigmas in other flowers, directed to find their paramours? Is this curious kind of storge produced by mechanic attraction, or by the sensation of love? The latter opinion is supported by the strongest analogy, because a reproduction of the species is the consequence; and then another organ of sense must be wanted to direct these vegetable amourettes to find each other; one probably analagous to our sense of smell, which in the animal world directs the new-born infant to its source of nourishment; and in some animals directs the male to the female; and they may thus possess a faculty of perceiving as well as of producing odours.

A most curious example of the existence of some kind of sense, which may direct the pistils, or female parts of the flowers of collinsonia, which way to bend for the purpose of finding the mature males, is related in Botanic Garden, Vol. I. Canto IV. l. 460, where some of the pistils mistake the males, or stamens, of the neighbouring
flowers

flowers for their own husbands ; and bending into contact with them become guilty of adultery. See Sect. VII. 2. 2. of this work.

9. Thus, besides a kind of taste or appetency at the extremities of their roots, similar to that of the extremities of our lacteal vessels, for the purpose of selecting their proper food ; and besides different kinds of irritability or appetency residing in the various glands, which separate honey, wax, resin, and other juices from their blood ; vegetable life seems to possess an organ of sense to distinguish the variations of heat, another to distinguish the varying degrees of moisture, another of light, another of touch, and probably another analogous to our sense of smell. To these must be added the indubitable evidence of their passion of love, and of their necessity to sleep ; and I think we may truly conclude, that they are furnished with a brain or common sensorium belonging to each bud.

But whether this brain, or common sensorium, resides in the medulla, or pith, which occupies the central parts of every bud and leaf, like the spinal marrow of animals, has not yet been certainly determined. By this medulla is meant only the pith of each individual bud, not that which is seen in the center of a tree, which, like the wood which surrounds it, has long ceased to have vegetable life.

The pith, or medulla of each bud, is supposed by its elasticity to push out the central part of the bud ; as the vesicular productions on the inside of young quills are supposed to push forwards their early growth, and in some birds are said by Mr. Hunter to receive air from the lungs. It is more probable that this pith, or medulla oblongata of plants, supplies the spirit of vegetation, since it exists in all buds in their most early state, and does not communicate from one bud to another, and thus distinguish them from each other, and evinces their individuality. See Sect. I. 8. and IX. 2. 4.

PHYTOLOGIA.

PART THE SECOND.

ECONOMY OF VEGETATION.

SECT. IX.

THE GROWTH OF SEEDS, BUDS, AND BULBS.

I. 1. SEEDS resemble eggs. 2. The embryo is of different maturity. The leaves visible in some seeds. 3. Why the plumula ascends and the root descends. Is nourished by the seed-lobes, by the fruit. Becomes a dwarf if deprived of them. Melons and cucumbers are too luxuriant. Turnep-seed should be new. 4. Seeds have hard shells, have acrid rinds with bitter or narcotic juices, but pure starch may be procured from them. 5. Umbilical vessels, and roots of seeds. Annual, biennial, and perennial plants. Reservoirs of nutriment in their roots. All plants are biennials. Bulbs and buds succeed each other many times before they flower. 6. Wheat. Stems and roots round the first joint. Has no necessity. Is greatly increased by transplanting. II. 1. BUDS are a viviparous progeny. Protected by scales and varnish. Grow by piping with more heat and moisture as they exhale less. Are individual, annual, or biennial plants. 2. Buds of herbs. Evergreens have no bleeding season. 3. Buds of deciduous trees are in different states of maturity, as in hepatica, daphne, osmunda. Some buds are invisible. 4. Importance of the pith like the spinal marrow; it lines hollow stalks. 5. Reservoir of nutriment for buds. Their umbilical vessels. 6. A bud contains many embryos. The first leaf-buds often destroyed by insects. The flower-buds only injured by them. 7. Vigorous branches produce leaf-buds, weak ones flower-buds. Why seedling apples are long before they bear. Why pears bear only at their extremities. 8. New buds may be made either leaf-buds by lopping a part of the branch, or flower-buds by bending the branch down, or cutting a ring in the bark, or strangulating

it with a wire. Debarked oaks pullulate. Sap-juice in the alburnum. 9. A pause in vegetation about midsummer. Trees then secrete nutriment in their roots and sap-wood for the new buds. Are then best transplanted without lopping their branches. 10. Caudexes of the buds form the bark, whose vessels inosculate. Heart-wood dies. Sap-wood acts as umbilical vessels, and afterwards as capillary tubes, or as capillary syphons. 11. Flower-buds perish without increasing the bark by new caudexes. Are convertible into leaf-buds. Vegetable monsters. 12. Central part of an adult bud. III. 1. BULBS. Leaf-bulbs precede flower-bulbs in the tulip as leaf-buds in apple-trees, as joints in the stalk of wheat. Solitary generation of insects. 2. Bulbs of onions. Orchis. Tulip. Hyacinth. Ranunculus. Iris. 3. Roots of potatoes. Wires of strawberries. Seeds of orchis. Flowers of potatoes. 4. Stem-bulbs on magical onions are similar to root-bulbs. 5. Root-grafting. Root-inoculation. Root-propagation. Suckers of trees. Root-buds of herbaceous plants. Internal parts of which decay. 6. Tuberous roots of turnep and carrot are reservoirs of nutriment for the succeeding flower-stem. No flower-bud is ever produced from a seed without previous leaf-buds. Why seedling apple-trees are ten or twelve years before they bear fruit. Magazines of aliment in almost all roots. 7. Use of the horse-hoe to accumulate earth round the wheat-plants. Wheat dropped on the soil shoots up but one stem. Covered with the soil it shoots up many. And transplanted deeper in the soil many more. Potatoes, vines, and figs, produce lateral roots from their joints. So does the bark if wounded circularly. Use of eating down forward wheat with sheep.

I. 1. HAVING treated of the physiology, we now step forwards to consider the economy of vegetation, as far as it may serve the purposes of agriculture and gardening.

After the production of the seed, or vegetable egg in the pericarp of flowers, and its ensuing impregnation by the farina of the anthers shed upon the stigma, a coagulated point appears on the seed-lobes according to the observations of Spallanzani, like the cicatricula on the yolk of the egg.

The seed continues to grow in the pericarp sustained by adapted secretions from the vegetable blood, which is previously oxygenated in

the bractes or floral-leaves of many plants; in others the seed is itself inclosed in an air-vessel probably for that purpose, as in *staphylea*, bladder nut, and *tagetes*, African marygold. At the same time a reservoir of nutriment is secreted, and deposited in the seed-lobes or cotyledons, which are single ones in the seeds of palms, grasses, and lilies; though twofold in those of most other herbs and trees; whence the strictest analogy exists between seeds and eggs.

2. In some seeds, when they leave the vegetable uterus, this embryo is much more mature than in others. In the seeds of the *nymphæa nelumbo* the leaves of the future plant were seen so distinctly by Mr. Ferber, that he found out by them to what plant the seeds belonged. The same in the seeds of the tulip-tree, *liriodendron tulipiferum*. *Amæn. Acad.* V. VI. No. 120. And Mr. Baker asserts, that on dissecting a seed of trembling grass, he discovered by the microscope a perfect plant with roots sending forth two branches, from each of which several leaves or blades of grass proceeded. *Microsc.* Vol. I. p. 252. While in other seeds the corculum, or heart only of the seed, is distinctly visible, as in the kernel of the walnut, and the seed of the garden-bean. So in the animal kingdom the young of some birds are much more mature at their birth than those of others. The chickens of pheasants, quails, and partridges, can use their eyes, run after their mothers, and peck their food, almost as soon as they leave their shell; but those of the linnet, thrush, and blackbird, continue many days totally blind, and can only open their callow mouths for the offered morsel.

3. When the seed falls naturally upon the earth, or is buried artificially in shallow trenches beneath the soil, the first three things necessary to its growth are heat, water, and air. Heat is the general cause of fluidity, without which no motion can exist; water is the menstruum, in which the nutriment of vegetable and animal bodies is conveyed to their various organs; and the oxygen of the atmosphere is believed to afford the principle of excitability so perpetually necessary

necessary to all organic life ; and which renders the living fibres both of the vegetable and animal world obedient to the stimuli, which are naturally applied to them.

Whence we may in some measure comprehend a difficult question ; why the plume of a seed sowed upon, or in the earth, should ascend, and the root descend, which has been ascribed to a mysterious instinct ; the plumula is stimulated by the air into action, and elongates itself, where it is thus most excited ; and the radicle is stimulated by moisture, and elongates itself thus, where it is most excited, whence one of them grows upwards in quest of its adapted object, and the other downward.

The first source of nutriment supplied to the feminal embryo, after it falls from the parent plant, exists in the seed-lobes, or cotyledons, which either remain beneath the earth, and are permeated by the umbilical vessels of the embryo plant, which absorb the mucilaginous, farinaceous, or oily matter deposited in them, as in the bean, pisum ; or the seed-lobes rise up into the air along with the young plant, as in the kidney-bean, phaseolus, become seed-leaves, and serve both as a nutritive and respiratory organ. These cotyledons or seed-lobes generally contain mucilage, as in quince-feed ; or starch, as in wheat ; or oil, as in line-feed. Some of these nutritive materials are probably absorbed unchanged, or dissolved only by the moisture of the earth ; others are converted into sugar partly by a chemical process, and partly by the digestive powers of the young plant, as appears in the process of germinating barley, and converting it into malt ; these reservoirs of nutriment are hence perfectly analogous to the white of the egg, a part of which is probably absorbed unchanged by the lymphatics of the young embryo, and a part of it converted into a sweet chyle for the nourishment of the chick, when it has acquired a stomach.

If the seed be deprived of these cotyledons, soon after the root appears, it will continue to grow, but with less vigour, and is said to produce

duce a dwarf plant from three to nine times less than the parent. Hence the seeds of plants, which are liable to produce too vigorous roots, and thence have not time to ripen their fruits in the short summers of this climate, or which fill our hot-beds with too luxuriant foliage, as melons, and cucumbers, should in this climate be kept three or four years; by which part of the mucilaginous, or farinaceous, or oily matter of the cotyledons becomes injured or decayed, and the new plant grows less luxuriantly.

Another source of nutriment for the seminal embryo of many plants exists in the fruit, which envelopes the stone or seed-vessel, after the growing fetus has burst its confinement, and so far resembles the yolk of the egg, which becomes a nutriment to the chick, after it has consumed the white, and eloped from its shell.

When mature fruit, as an apple or a cucumber, falls upon the ground, it supplies, as it ripens or decays, a second source of nourishment, which enables the inclosed seeds to shoot their roots into the earth, and to elevate their stems with greater vigour. Hence fruits generally contain a saccharine matter, or juices capable of being converted into sugar, either by a spontaneous chemical process, as in baking four apples; or by a vegetable process, as in those four pears, which continue to ripen for many months both before and after they are plucked from the tree, as long as life remains in them; that is, till they ferment or putrify; and lastly, by the digestive power of the young embryo, as above mentioned.

If the seed be deprived of the fruit, it will indeed vegetate, but with less vigour. Hence those seeds which are liable to produce too vigorous shoots for this climate, as the seeds of melons and cucumbers, should be washed clean from their pulp, before they are hoarded, and preserved three or four years before they are sown in hot beds. But those seeds, which are sown late in the season for the purpose of producing winter fodder, as the seeds of turneps, should be collected and preserved with every possible advantage; and on this

account new feed is much to be preferred to that which has been long kept.

4. Many seeds when mature are dispersed far from the parent tree, for the purpose of their growth, by various contrivances, as mentioned in Sect. VII. 2. 5. Some of these are surrounded with hard shells, which are impenetrable by insects, as they lie on the earth to take root, as peaches, nectarines, nuts, cocoa-nuts. Other seeds are furnished with an acrid covering to prevent the depredation of insects, as the peel of oranges and lemons, the outward husk and inward rind of walnuts, and of cashew-nuts, and the skin of mustard-feed, and rape-feed; other seeds for the same purpose abound with bitter or narcotic juices, as the horse-chestnut, acorn, apricot, cherry, many of which supply materials to the shops of medicine, and may supply nutriment in times of scarcity; as the starch, which they contain, may be procured by grating them into cold water, and washing away the mucilage, and the poisonous material, which adheres to it, or which is soluble in water.

5. The plumula of the seed, or embryo plant, absorbs the nutriment laid up for it in the seed-lobes by vessels, which permeate them for that purpose, and have been termed umbilical vessels; and afterwards shoots its roots down into the fruit, or into the earth, in search of other nourishment; and expands its leaves in the air as an organ of respiration.

Those plants, which are usually termed annuals, produce their flowers and die in the same year in which their seeds are sown; as barley, oats, and a variety of garden flowers. These nevertheless in accurate language should be termed biennials, because the seed in this climate is produced in one summer; and the embryo plant becomes mature in the next; as the seed is generally preserved in our granaries, or seed-boxes, and not committed to the ground till the ensuing spring; for many of these vegetables are not natives of this climate,

climate, and would perish if the seeds were sown in autumn, when it is naturally scattered on the earth.

Those which are usually termed biennial plants, differ from the former, first in the time of sowing the seed, which is generally in the early autumn, as soon as it is ripe, as of turneps, carrots, wheat; and thus these produce their flowers in the second year after the seed is sown, which has given them the name of biennials. Many of these plants, perhaps all of them, lay up a reservoir of nutritious matter during the summer or autumn in their roots. This nutriment is secreted from the vegetable blood, which is previously oxygenated for that purpose in the large leaves, which generally surround the caudex of the plant, as in turneps and carrots. These leaves survive the winter in many plants, which the more succulent stems probably would not; and the nutriment deposited in the root is expended in the growth of the stem and the production of seed in the ensuing spring. As in these vegetables one of our summers is too short for their growth from the seed to the fructification; and it is for this reservoir of nutriment that these plants are generally cultivated.

But those plants, which are termed perennial, when first raised from seed, are many of them some years before they produce flowers. Some of them form bulbous roots, as the tulip, hyacinth, onion, which are three or four years before they flower, during which time I believe all the bulbs die annually, producing one larger than that of the preceding year, and perhaps some smaller ones, all which annually increase in size till they flower. The same occurs in potatoe-roots raised from seed, which do not flower as I am informed till the third year, and then only those which seemed of stronger or forwarder growth.

Other perennial plants have palmated or branching roots; in some of these, as in seedling apple-trees, the flower is said not to appear till ten or twelve years after the seed is sown; the buds nevertheless annually dying and producing other buds over them, perhaps more

perfect ones, as they acquire after a few years the power of producing sexual organs, and in consequence a feminal progeny. In these perennial herbaceous plants and trees a magazine of nutriment is provided in their roots or sap-wood, to supply the new buds, which are to grow in the ensuing spring.

Whence it appears, that all the vegetables of this climate may be termed biennial plants; as the seeds of some, and the buds or bulbs of others, are produced in one summer, and flourish and die in the next; those which are called annuals or biennials leaving behind them a future progeny of seeds only; those, which are termed perennial herbaceous plants, leaving behind them the first year or two a progeny of bulbs or root-buds only, and afterwards a progeny of seeds also; while the perennial arborescent vegetables leave behind them a progeny of buds only for several successive years, and afterwards a progeny of both buds and seeds.

Thus the bulb from a tulip-seed produces a more perfect bulb annually, till it flowers, I believe, on the fifth year. It then produces a flower, and also one perfect bulb, which flowers the next year; and some other less perfect bulbs, which are succeeded by more perfect ones annually, till they also flower. Whence I conclude, that no tulip bulb flowers till the fourth or fifth generation.

It is probable, that a similar circumstance occurs in other vegetables, as in apple-trees; and that the buds of these do not produce sexual organs, and a consequent feminal progeny, till the twelfth or fourteenth generation of the bud from the seed; each of those buds nevertheless producing one principal bud annually more perfect than itself, and many lateral buds less perfect than itself; that is, at a greater distance from that state of maturity which enables it to form a flower. This art of distinguishing the greater or less maturity of buds is a matter of great importance in the management of fruit-trees, as in many of them the central bud becomes a spur one year, and flowers the

the next ; and the lateral buds one or two years afterwards, as will be mentioned in Sect. XV. on the production of fruit.

6. In wheat there exists about the caudex a reservoir of nutritious juices deposited in the autumn for the purpose of raising the stem in the ensuing spring like that of turneps and carrots ; but which is attended with other circumstances peculiar I suppose to the grasses, and other plants, which possess only one cotyledon or seed-lobe. The early leaf, which surrounds the first joint of the stem, withers, as the spring advances ; in which joint it had previously deposited a saccharine juice, and probably some new embryo buds were at the same time generated in the caudex ; for through this withered leaf, which surrounds the first joint of the stem within the earth, a circular set of new stems issue adhering to it, and a circle of roots below them adhering to the caudex or base of it. These new buds rise into air, and shoot their roots into the earth ; and in this manner many stems are produced in the spring from one seed sowed in the autumn preceding ; though in some kinds of wheat the whole process of the seed rising from earth, and producing other stems round the principal one, and of ripening its seeds, may be performed in one summer even in this northern climate.

Another peculiarity attends the growth of wheat and other grasses ; the leaf, which surrounds and strengthens the stem by its foot-stalk, deposits at every lower joint a saccharine matter for the purpose of nourishing the ascending part of the young stem ; and in the uppermost joint, I suppose, to serve instead of honey for the stamens and stigmas, as their flowers have no visible nectary ; and as the scales of the flower may with good reason be esteemed a calyx rather than a corol, according to the opinion of Mr. Milne ; as these scales attend the seed-vessel to its maturity, which the corol does not. Milne's Botanical Dict. Art. Gramina.

Owing to this secretion of saccharine matter at the foot-stalk of every leaf, and its collection round the joints of grasses, it happens that

that when these joints are surrounded with moist earth, and are placed but a certain depth from the air, that new buds will put forth round these joints, and strike their roots into the soil. Whence the agrarian husbandman may derive great advantage from transplanting his wheat, after it has produced a circle of new stems from the first joint of the straw; for if he then parts and replants them an inch or two deeper in the ground, so as to cover the first joint of each of these additional stems, he may multiply every one of them four or six times, and thus obtain twenty or thirty stems from one original seed. See No. III. 1. and 7. of this section.

II. 1. Other vegetable embryos are produced in the buds on the stems or branches of trees, which may be termed the viviparous progeny of plants, in contradistinction to those from seeds, which may be termed their oviparous progeny. These buds are either leaf-buds or flower-buds, or both in one covering; the bud is termed *hybernaculum*, or winter-cradle, of the embryo shoot, and is covered with scales, and often with a resinous varnish, as in *tacamahacca*, to protect it from the cold and moisture of the ensuing winter, and from the depredation of insects.

These by inoculation or ingrafting on other stems of trees, or by being planted in the earth, become plants exactly similar to their parents. A small glass inverted over these buds, when set in the earth, contributes to insure their growth by preventing too great an exhalation; otherwise they are liable to perspire more than they can absorb, before they have acquired roots; this the gardeners call *pip-ing a slip*, or a cutting, of a plant. In this situation a greater heat may be given them, as in hothouses, without increasing their quantity of perspiration, which ceases as soon as the air in the glass is saturated with moisture; and the increase of heat much contributes to the protrusion of their roots and new buds, as they can at the same time bear to be supplied with a greater quantity of moisture.

Every bud of most of the deciduous trees of this climate may there-

fore be considered as an individual biennial plant, as distinctly so as a seed; that is, the bud like a seed is formed in one summer, grows to maturity in the next, and then dies. In some trees nevertheless of this climate, as the mock orange, philadelphus, acacia, viburnum; and in the evergreen shrubs or trees, as holly, laurel, vinca, heath, and rue; and in all those herbs commonly called annuals; and in most of the trees of warmer climates; the buds appear to be formed in the vernal months, and to arrive at their maturity during the same year; and may therefore properly be called annual plants.

2. The bud of these herbs, which are commonly called annuals, rises in the bosom of a leaf; and, as it adheres to its parent, requires no female apparatus to nourish it, but gradually strikes down roots from its caudex into the ground, which caudex forms a part of the bark of the increasing plant. This occurs in those herbaceous vegetables, which have just risen from seeds; the buds of which are properly individual annual plants, which grow to maturity adhering to the parent, and do not therefore resemble a seed or egg, as there is no reservoir of nutriment laid up for them.

This circumstance also happens, I suppose, to the evergreen shrubs and trees of this climate, as to heath, rue, box, pine, laurel; for in these vegetables, as the leaf does not die in the autumn, it continues to oxygenate the blood, and to supply nourishment to the bud in its bosom during the fine days of winter, and in the spring, and survives till near midsummer; that is, till the new bud has expanded a leaf of its own. Whence I suppose these evergreens lay up in summer no store of nutriment in their roots or alburnum for the sustenance of their ensuing vernal buds; and have thence probably no bleeding season like deciduous trees.

But the embryo in a bud of a deciduous plant leaves in the spring of the year its winter cradle, or hybernaculum, like the embryo in a seed, or a chick in the egg; and like these the young plants of different vegetables have previously arrived at different states of maturity.

rity. Thus Mr. Ferber asserts, that he was delighted in observing in the buds of *hepatica*, and *pedicularis hirsuta*, yet lying in the earth, and in the gems of the shrub *daphne mezereon*, and at the base of *osmunda lunaria*, a perfect plant of the future year discernible in all its parts; thus also in horse-chestnut the leaves, and in cornel-tree the flowers, are each distinctly visible during the winter in their respective buds. *Amœn. Acad. Vol. VI. No. CXX. Milne's Dict. Art. Gemma.*

While in buds of many other trees, and probably in all the more backward buds, which are formed late in the summer on the lower parts of branches, and much deprived of light and air, the embryo is not so forward as to be easily discernible; and in those shrubs or trees, which are deciduous in this climate, and yet have no apparent buds in winter, as the philadelphus, mock orange, viburnum, and many shrubs. I suspect there is nevertheless an embryo secreted from the blood at the foot-stalk of each leaf, though it is not so forward as to protrude through the bark, and produce a prominent bud, or hybernaculum. The same I suspect to occur in respect to trees, which lose their leaves in winter, in warmer climates, in which they are said not to produce autumnal buds; as I can not conceive by what means fresh leaf-buds can be generated in the spring, when the leaves, which constitute the lungs of the mature living part of the tree, are dead; and the whole of that mature living part, or last year's bud, consequently dead along with them. But if the caudex of the new bud be generated without the plumula, or visible bud, it can certainly produce a plumula for itself in the ensuing spring, as is seen by the production of new buds, when a branch is cut off, round the remaining trunk, as is done frequently to the stems of willows.

In similar manner the viviparous offspring of different animals arrive at different states of perfection before they are born, as calves and foals can stand erect in an hour, and quickly learn to use their eyes, and to run after their mothers; while the blind puppy, and kitten,

and the downless rabbit, are long before they can leave the nest which the parent has provided for them.

4. The presence of the pith or medulla is of great importance to the growth of the new bud, as may be observed by gradually slicing a shoot of a horse-chestnut in autumn, or in the early spring. The rudiments of the seven separate ribs of the late parent-leaf, and the central pith of the bud in its bosom, are seen to arise or terminate near the pith of the parent shoot, where the embryo plumula is probably secreted by a gland at the bottom of the parent leaf-stalk, finds there its first reception and nourishment, and is gradually protruded and elongated by the pith, which exists in its center, as the bud proceeds, and thus constitutes the ascending caudex or uterus of the new bud; which is resembled by the wires of strawberries, and other creeping vegetables; whereas the descending caudexes of the new buds, which form the filaments of the bark of trees, are secreted from the various parts of the old bark in their vicinity; all which probably occur at the same time by sympathy, as shewn in Sect. VII.

The pith thus appears to be the first or most essential rudiment of the new plant, like the brain or spinal marrow, medulla oblongata, which is the first visible part of the figure, I believe, of every animal fetus, from the tadpole to mankind.

In those plants which have hollow stems, this central cavity, though not filled with the pith or medulla, appears to be lined with it; as in *picris* and *tragopogon*; in the former the stem is not only lined with the pith, but wherever a new bud is generated on the summit of the ascending stem, or in the bosom of a leaf, a membranous diaphragm divides the cavity, and is covered with this medullary substance, which division thus distinguishes one bud from another; and in slicing away the part of the stem of *tragopogon*, where the new lateral bud adheres, the medulla or pith in the center of the bud is seen to commence near that membrane which lines the stem, and to pass through the circle of arterial, venal, and absorbent vessels, which constitute

the ascending caudex, or uterus, of the new bud, while the descending caudex of it is secreted from the various parts of the older bark in its vicinity.

Something similar to this mode of the production of the buds of trees had not escaped the ingenious Mr. Bradley, who asserts, "that buds have their first rise in the pith; they are there framed, and furnished with every part of vegetation, and forced forwards to meet the air through the tender bark, and would drop on the ground, if they were not restrained by vessels, which serve as roots to nourish them; and thus as a seed takes root in the earth, a bud takes root in the tree; but with this difference, that the seed has lobes to supply it with nourishment, till it can select juices from the earth; but the bud has no occasion for lobes, because it takes root immediately in the body of the tree, where the proper juices are already prepared for it." *Discourses on Growth of Plants*, 1727, p. 56.

5. As the seed was nourished in the pericarp by an adapted secretion from the vegetable blood oxygenated in the bractes or floral-leaves; and as a reservoir of nutriment was also prepared for it afterwards in the seed-lobes and fruit: so the bud is at first nourished in the bosom of its parent-leaf by an adapted secretion from the vegetable blood; and continues to be so nourished in annual herbs and evergreen trees, till it protrudes and expands its own leaf; but if it be a bud of a deciduous plant, which must lose its parent-leaf in winter, a reservoir of nutriment is prepared for it in the roots of some plants, as in carrots, turneps, liquorice, fern; and probably both in the roots and alburnum, or sap-wood, of trees.

Thus in the spring the umbilical vessels belonging to each individual biennial plant, or bud of a tree, absorb moisture from the earth, and propel it upwards through the roots and alburnum, where it is mixed with a nutritious material, and carried upwards in some trees with a power equal to the pressure of the atmosphere, as in the vine, vitis;

vitis ; the birch, *betula* ; and the maple, *acer* ; which at that season bleed at every wound, as treated of in Sect. III.

6. At this time the buds begin to swell, and to shoot roots downwards from their caudexes into the earth ; the intertexture of these caudexes constitutes a new bark over the old one, consisting of arteries, veins, and absorbents, as described in Sect. I. 3. Each bud then also puts forth a leaf, which is a respiratory organ, and resembles in many respects the lungs of animals, as described in Sect. IV. but differs from them in this circumstance, that the leaf requires light as well as air for the purpose of perfect respiration, as will be treated of in the Section on Light.

Each embryo of a leaf-bud is thus furnished with its proper respiratory organ ; and as many new embryos were generated during the summer in each leaf-bud, they now pullulate in succession ; each of which has like the first its appropriate leaf, which, as they successively advance, compose the annual shoots or sprigs of trees ; which in some plants become of great length, as in vines, and willows, consisting of twenty or thirty new leaves. Hence if the first set of leaves be destroyed by vernal frosts, as frequently happens to ash-trees, *fraxinus*, and to the weeping willow, *salix babylonica* ; or by the depredation of insects, which often injures our fruit-trees ; and perpetually occurs in this climate to the spindle-tree, *euonymus* ; and in Italy to the white mulberry-tree, which has its first leaves plucked off for the food of silk-worms, and to the tea-tree in China ; a second set of leaves succeeds, which belong to the second embryos of the same bud.

But when the bractes or floral-leaves are destroyed by insects, as sometimes happens to currant-trees, and apple-trees ; the fruit in the pericarp does not perish, like the first embryo of the leaf-bud above mentioned ; because it is still supplied by the absorbent system of the caudex and roots of the flower-bud, which compose a part of the bark, and pass into the ground ; but the fruit becomes sour and less per-

fect from the want of a due oxygenation of the juices, from which it is secreted; though its glands may probably also receive some oxygenated blood by the inoculation of the vessels of different buds, whether flower-buds or leaf-buds, with each other in the bark, on supposition that they are not all of them totally destroyed.

7. In the axilla of each leaf is generally produced about midsummer either a new leaf-bud or a flower-bud; if it be a leaf-bud, it becomes a branch the next year, producing many other leaves, and many other buds; if it be a flower-bud, the growth ceases, terminating in the seed. During the greater vigour of the plant the leaf-buds are solely or principally produced, as in young healthy trees; but when the vessels of the bark become further elongated, as the plant grows taller, the nutritive juices are less copiously supplied, or the buds are become more mature, and the production of flower-buds succeeds as in Mr. Walker's experiments the sap of the birch-tree in the spring was two or three weeks later in ascending to the top of a high tree, than to the lower branches. Edinb. Transact. Vol. I.

Hence it happens, that the grafts from strong seedling apple-trees do not bear fruit, till they are twelve or twenty years old; while the grafts from old weak trees will bear copiously in two or three years, and hence very vigorous trees, as pears, produce fruit only at their extremities; but if you decorticate about an inch of a branch of a vigorous pear-tree, and thus weaken it; that branch will flower, and bear fruit at every bud like trees of less vigour.

It should be here observed, that the words strength and weakness, when applied to the growth of vegetables, are in reality metaphorical terms; or express the effect or consequence of their producing leaf-buds or flower-buds, rather than the cause of it, whereas it is the facility with which the long caudexes of the new buds, which form the new filaments of bark, can be generated, which increases the number of leaf-buds, and gives the tree a luxuriant or vigorous appearance; and the difficulty of generating these new caudexes which
increases

increases the flower-buds, and thus gives a less vigorous appearance to the tree.

The generation of buds seems to require a less perfect apparatus than the generation of seeds; as that of buds always precedes that of seeds, both in trees and herbs; and because the caterpillar is converted into a butterfly solely for the purpose of feminal propagation; whereas the polypus can only propagate laterally, or by buds. Hence the age of the plant is another necessary circumstance to the production of flowers, fruit, and seeds, as appears in tulips, and hyacinths, as well as in apple-trees and pear-trees.

8. About midsummer the new buds are formed; but it is believed by some of the Linnean school, that these buds may in their early state be either converted into flower-buds or leaf-buds, according to the vigour of the vegetating branch. Thus if the upper part of a branch be cut away, the buds near the extremity of the remaining stem, having a greater proportional supply of nutriment, and possessing a greater facility of producing their new caudexes along the bark, will become leaf-buds; which might otherwise have been flower-buds; and on the contrary, if a vigorous branch of a wall-tree, which was expected to bear only leaf-buds, be bent down to the horizon or lower, it will bear flower-buds with weaker leaf-buds, as is much exemplified by Mr. Hitt in his Treatise on Fruit Trees.

The theory of this curious vegetable fact has been esteemed difficult, but receives great light from the foregoing account of the individuality of buds. Both the flower-buds and leaf-buds die in the autumn; but the leaf-buds, as they advance, produce during the summer other leaf-buds or flower-buds in the axilla of every leaf; which new buds require new caudexes extending down the bark, and thus thicken as well as elongate the branch; whereas the flower-buds shed their seed, when they perish in the autumn, and thus require no place on the bark for new caudexes. Hence when the summit of a branch is lopped off, the buds near the extremity of the remaining
I stem

stem produce new leaf-buds with greater facility, as there is more room for their new caudexes to be generated along the descending bark. But if a vigorous branch be bent down to the horizon, or below it, the bark is compressed beneath the curve, and extended above it, and thus the production of new caudexes along the bark is impeded, and in consequence less leaf-buds and more flower-buds will be generated, or the former converted into the latter; which require no new caudexes. And on this circumstance principally depends the management of wall-fruit trees, and of espalliers.

For the purpose of thus converting leaf-buds into flower-buds Mr. Whitmill advised to bind some of the most vigorous shoots with strong wire, and even some of the large roots; and Mr. Warner cuts, what he calls, a wild-worm about the body of the tree; or scores the bark quite to the wood like a screw with a sharp knife. Bradley on Gardening, Vol. II. p. 155. Mr. Fitzgerald produced flowers and fruit on standards and wall-trees by cutting off a cylinder of the bark, three or four inches long, and replacing it with proper bandage, (Philos. Trans. Ann. 1761) as described in Sect. XV. 1. 3. of this work. M. Buffon produced the same effect by a straight bandage put round a branch, Act Paris, Ann. 1738; and concludes that an ingrafted branch bears better from its vessels being compressed by the callus produced, where the grafted scion joins the stock.

It is customary to debark oak-trees in the spring, which are intended to be felled in the ensuing autumn; because the bark comes off easier at this season, and the sap-wood, or alburnum, is believed to become more durable, if the trees remain till the end of summer from their expending their saccharine sap-juice in the ensuing foliage, and thus being less liable to ferment and putrify. The trees thus stripped of their bark put forth shoots as usual with acorns on, the sixth, seventh, and eighth joint, like vines; but in the branches I examined the joints of the debarked trees were much shorter than those of other oak-trees; the acorns were more numerous; and no

new buds were produced above the joints which bore acorns. From hence it appears that the branches of debarked oak-trees produce fewer leaf-buds, and more flower-buds; which must be owing to the impossibility of their producing new caudexes down the naked branches and stem for the embryo progeny of leaf-buds.

The pullulation of leaves on debarked oaks demonstrates, that the reservoirs of nutriment deposited in the preceding summer for the use of the vernal buds must be in this alburnum; and that it is this saccharine matter which induces the alburnum to ferment and rot sooner than the internal wood. Thus Dr. Walker found on nice inspection the sap-juice to flow from the ligneous circles of the alburnum as well as between them, when a fresh piece was cut off from a cicatrized part, and also between the wood and the bark. Edinb. Transact. Vol. I. He also observed that oak, ash, elm, aspen, hazel, and hawthorn, do not bleed; and that the birch, plane, and maple bleed the most, and that the grey willow, *salix caprea*, does not bleed, but the sap-juice rises visibly between the wood and the bark, so as to make the bark separate easily from the wood. From all these facts it may be inferred, that the saccharine matter, which is dissolved in the sap-juice, is deposited in the autumn in the roots of some trees, and in the alburnum of others, or in both; as manna is found in the wood of the manna-ash; and sugar in the joints of many grasses and of the sugar-cane, and in the roots of liquorice, beets, and many other herbaceous vegetables.

9. About Midsummer, after the new buds appear in the bosom of every leaf, many authors have remarked that there seems to be a kind of pause in vegetation for about a fortnight, which they have ascribed to different causes. At this time I suspect the reservoir of nourishment for the new buds is forming about the roots or in the alburnum of the tree; and that the caudexes and umbilical vessels of the new buds are also at this time forming down the bark, and terminate in those nutritious reservoirs in the roots or new alburnum like the umbilical

umbilical vessels called feminal roots, which are visible in many feeds.

That this system of umbilical vessels is possessed of a great power of absorption in the roots of trees is certain from the force, with which the sap-juice was propelled upward from a vine-stump in Dr. Hales' experiment. That the sap-juice thus propelled upwards nourishes or expands the leaf of each new bud appears from the experiments of Dr. Walker; as the leaves began to unfold at the same height, as the wounded wood began to bleed, and that these vessels pass through or constitute the sap-wood is evinced by the growth of the buds on oak-trees, after the bark is almost totally taken off.

The roots of trees are at this time protruded with greater vigour, as observed by the ingenious Mr. Bradley, who on that account prefers the midsummer season for transplanting trees, if they are not to be removed to any great distance; and adds, that the new shoots in the following spring will put forth with much greater force, and the tree will thence be almost a year forwarder in its growth, than if it remains untransplanted till the winter. Discourses on Earth and Water. This seems to be owing to the destruction of much of the nutritious matter deposited in the roots for the use of the new buds, which is torn off in transplanting, and which can only be replaced about Midsummer or soon after.

Mr. Bradley further adds, that when trees are thus transplanted at Midsummer, no part of the top or branches, or foliage, should at that time be cut off; which well accords with the theory above delivered; as it is from the vegetable blood, which is oxygenated by its exposure to the air through the thin moist pellicle on the upper smooth surfaces of these leaves, that the nutriment for the expansion of the buds in the succeeding spring is secreted or produced; and hence if these leaves are prematurely destroyed, the vernal growth of the buds must receive injury; as the reservoir of future nutriment for them will be less in quantity; but if some of the branches are
lopped

lopped during the winter, the remainder will protrude more vigorous shoots, as their share of the reserved nutriment will be greater.

10. The umbilical vessels of the new buds of deciduous trees, which are analogous to those which permeate the lobes of the feed, are extended downward in the bark about midsummer, and terminate in certain reservoirs of nutriment, which are at this time secreted from the vegetable blood oxygenated in the leaves. This bark now consists of an intertexture of the caudexes of the present leaves, which were buds in the last summer, and are now adult vegetable beings; and of the embryon caudexes of the new buds; and of the umbilical vessels of the new buds; it will become alburnum or sap-wood during the autumn or ensuing spring, and will be gradually covered over with a new bark consisting of the mature caudexes of the new buds, while that, which was the alburnum in the preceding spring, will become a circle of lifeless timber, interior to the circle of alburnum.

The vessels of this new bark, though they consist of the caudexes of the individual adult leaves, and the umbilical vessels of the individual young buds, evidently inosculate; because, when some buds are rubbed off or destroyed, those in their vicinity grow with greater vigour; as the daily experience of pruning all kinds of trees evinces. The facility with which the ruptured vessels of vegetables inosculate into each other, or grow together, corresponds with that of animal vessels in their inflamed state. Thus a bud taken from one tree, and inserted into any part of the bark of another tree of the same genus, or ingrafted on it, presently receives nutriment, and grows to it by the reciprocal inosculatation of the wounded vessels, in the same manner as a transplanted tooth; or as the fingers are liable to grow together after having been excoriated by a burn; or as the inflamed lungs and pleura are liable to adhere, and intermix their blood-vessels. See Sect. III. 2. 7.

During the winter, when the leaves die and fall off, the arterial and venous systems, which belonged to them, and which composed the

greatest part of the bark, seem to lose their vegetable life at the same time, and to coalesce, and form the alburnum, or sap-wood ; but the umbilical vessels belonging to the new buds, which are intermixed with this alburnum, remain alive ; and at the returning spring act with astonishing vigour ; as described in Sect. III. 2. 2.

As the spring advances, the umbilical vessels, after having drank up the reservoirs of nutriment, which were deposited about the roots, and having thus nourished and expanded the new leaves, cease to act ; and the alburnum gradually changes into hard wood, called the heart of the tree ; which no longer possesses vegetative life ; and is now only useful to elevate and sustain aloft the swarm of biennial plants, which cover it ; and was probably originally produced for this purpose in the contest of all vegetables for light and air.

This inert or lifeless state of the central parts of trees, called the heart-wood, is evident from those old oaks and willows, which have lost their internal hard wood, and are become quite hollow, consisting only of their bark and alburnum, and yet are furnished with many healthy branches. But the umbilical vessels of the alburnum possess the properties of capillary tubes, or of a sponge, after they are extinct, and cease to act as umbilical vessels ; and thus may occasionally attract moisture, or suffer it to pass through them mechanically ; whilst the new bark, which consists of an intertexture of the caudexes of each bud with their radicles, may occasionally absorb this moisture from the capillary vessels of the alburnum, which may be compared to the upper stratum of the soil attracting by capillary power the moisture from the soil immediately beneath it, which may exhale into the atmosphere, or be imbibed by the roots of vegetables by the superior living power of their absorbent mouths.

That the vessels of the alburnum in their living state possess the property of conveying the sap-juice, which is propelled upwards in the early spring by the absorbent terminations of the roots, is visible in decorticated oaks ; the branches of which expand their buds, like
those

those of the birch and vine in the bleeding season. That the vessels of the alburnum in their living state occasionally act as capillary syphons, through which the sap-juice is first pushed upwards by the absorbent extremities of the roots, and afterwards returns downwards partly by its gravitation in branches bent below the horizon, appears from an experiment of Dr. Walker, mentioned in Sect. III. 2. 4.

Lastly, that the vessels of the alburnum after their vegetable life is extinct, possess a power of capillary attraction of the sap-juice, or of permitting it to pass through them occasionally, appears from the following experiments. First, a branch of a young apple-tree was so cankered, that the bark for about an inch quite round it was totally destroyed. To prevent the alburnum from becoming too dry by exhalation, this decayed part was covered with thick white paint; in a few days the painting was repeated, and this three or four times, so as to produce a thick coat of paint over the decayed part, or naked alburnum, extending to the ascending and descending lips of the wound; this was in spring, and the branch blossomed and ripened several apples.

In a garden in Lichfield about four years ago a complete cylinder of bark about an inch long was cut from a branch of a pear-tree nailed against a wall; the circumcised part is now not more than half the diameter of the same branch above and below it; yet this branch has been full of fruit every year since, when the other branches of the tree have borne only sparingly. I lately observed, that the leaves of this wounded branch were smaller and paler, and the fruit less in size, and ripened a fortnight sooner, than on the other parts of the tree. Another branch of the same tree has a part of the bark taken off about an inch long, but not quite all round it, with much the same effect.

The existence of capillary tubes in dead sap-wood is visible in a piece of dry cane, which permit water or smoke to pass through them; and in the exhausted receiver of an air-pump both water and

quicksilver may be made readily to pass through pieces of the dry alburnum of wood by the pressure of the atmosphere.

11. The flower-buds of many trees arise immediately from the last year's terminal shoots, or spurs, either accompanied with leaf-buds, or separately, as in apple and pear-trees. Other flower-buds arise from the shoots of the present year alternately with leaf-buds, as those of vines, and form the third or fourth buds of the new shoots. They differ from leaf-buds in this circumstance, that they perish when their seeds are ripe, without producing any addition or increase to the tree; whereas when the leaf-buds perish in the autumn, their caudexes, the intertexture of which constitutes the bark of the tree, gradually become converted into alburnum, or sap-wood; over which the new leaf-buds shoot forth their caudexes and radicles, or insert them into it, and gradually fabricate the new bark and root-fibres.

It was before mentioned, that it is believed by some disciples of the Linnean school, that about Midsummer leaf-buds may be changed into flower-buds, or flower-buds into leaf-buds; and that even after the vegetable embryos are generated. And that this may be effected by weakening or strengthening the growth of the last year's buds, which secrete these new ones from the vegetable blood, and nourish them in their infant state. Thus if some inches of the extremity of a branch be lopped off at Midsummer, as is sometimes done by unskilful gardeners, the remaining few buds will become more vigorous, and consequently produce leaf-buds instead of flower-buds; or perhaps the embryos already formed may be converted from one kind to the other. The contrary may occur, if a vigorous branch of a wall-tree be bent down beneath the horizon, or so much as to impede the generation of new caudexes; or if the leaf of the parent-bud be taken off, soon after the plumula or apex of the new bud is generated; and thus the new caudex along the bark may be prevented by deficiency of nutriment.

The probability of this idea of transmuting flower-buds and leaf-buds

buds into each other is confirmed by the curious conversion of the parts of the flowers of some vegetable monsters into green leaves; if they be too well nourished, after they are so far advanced as to be unchangeable into leaf-buds. Thus in the *plantago rosea*, rose-plaintain, the divisions of the spike become wonderfully enlarged, and are converted into leaves; the chaffy scales of the calyx in *xeranthemum*, everlasting, and in a species of *dianthus*, pink, and the glume of some alpine grasses, and the scales in the ament of the *salix rosea*, rose-willow, grow into leaves, and produce other kinds of vegetable monsters.

Add to this, that the petals of the *helleborus niger*, or christmas-rose, are beautifully white till the seed is impregnated; and then they change into green leaves, forming a calyx. And lastly, in other flowers a bud or bulb succeeds the impregnation instead of a seed, as in *polygonum viviparum*, viviparous bistort; and in *allium magicum*, magical onion; the same occurs in many of the alpine grasses, and in the *festuca dumetorum*, fescue grass; all which are in some degree analogous to the supposed conversion of early flower-buds into leaf-buds; for in these magical onions, and other bulbiferous flowers, the bractes or floral-leaves, which at first secrete nourishment for the pericarp and seeds of the plant, assume a new office, and secrete a magazine of nourishment for the new bulb, as appears in the concentric fleshy membranes, which surround the new summit-bulbs of the *allium magicum*, and the cloves of garlic.

12. The central part of an adult bud therefore consists first of a conjunction of the blood-vessels from above and below, which exists in the caudex of the bud between the beginning of the leaf-vessels and the beginning of the root-vessels; the circulation resembling that of many insects, of fish, and in the livers of quadrupeds, as shewn in Sect. V. 2. Secondly, there is probably at the same place a conjunction of the absorbent vessels correspondent to the receptaculum chyli of animals. Thirdly, there exists in each bud an organ
of

of reproduction, which in a leaf-bud produces the lateral or paternal offspring, and in a flower-bud the feminal or amatorial one. Fourthly, a center of nervous influence, as a brain, or spinal marrow, or common sensorium, exists in each bud; and probably resides near this junction of the blood-vessels of the leaf and root, and of the absorbent system, along with the organ of reproduction in the caudex gemmæ.

III. 1. THE BULBOUS ROOTS of some perennial herbaceous plants, and the root-scions of other perennial herbaceous plants, are similar in this respect, which distinguishes them from buds; that they are generated on the broad caudex of the plant within the ground, or in contact with it, and immediately shoot down their new roots into the earth. Whereas buds are formed above the soil on the long caudexes, which constitute the filaments of the bark of trees, and shoot down new roots into the earth from the lower end of these elongated caudexes.

Bulbs have not improperly been called subterraneous buds; and like them they may be divided into leaf-bulbs and flower-bulbs. When a tulip-seed is sown, it produces a small plant the first summer, which in the autumn dies, and leaves in its place one or more bulbs. These are leaf-bulbs, which in the ensuing spring rise into stronger plants than those of the first year, but no flowers are yet generated; in the autumn these perish like the former, and leave in their places other leaf-bulbs stronger, or more perfect, than their preceding parents. This succession of leaf-bulbs continues for four or five years, till at length the bulb acquires a greater perfection or maturity, necessary for feminal generation, and produces in its place a large flower-bulb in the centre with several small leaf-bulbs around it.

This successive formation of leaf-bulbs in bulbous rooted plants previous to the formation of a flower-bulb is curiously analogous to the production of leaf-buds on many trees for several years before the production of flower-buds; thus the apple-trees, *pyrus malus*, which are raised from seeds, generate only leaf-buds for ten or twelve years,
and

and afterwards annually generate both flower-buds and leaf-buds. From whence it would seem, that the adherent lateral or paternal progeny is the most simple, and easiest, and consequently the first mode of reproduction; and that the amatorial or feminal progeny is on this account not generated till the maturer age or more perfect state of the parent-bud.

A still more curious analogy to this circumstance of a succession of leaf-buds and leaf-bulbs preceding the formation of flower-buds and flower-bulbs exists in the growth of wheat, triticum, and other grasses; but with this difference, that a succession of leaf-buds, as of two, or three, or four, are produced in the same year previous to the flower-bud. At the first joint of the stem of wheat, on or within the surface of the earth, a leaf is produced; from which rises the principal or central bud, and around it many new buds, which strike their roots into the soil. After this central bud, and those around it, have arisen six or eight inches, a new leaf and a new leaf-bud rises on each of them, producing a second joint of the stem; and lastly, a flower-bud is generated at the summit, which are all evidently distinct vegetable beings, as there is a division across the stem at each joint, which shews there is no connexion of the pith, or brain, or spinal marrow, between the lower and upper joints, as mentioned in Sect. I. 8.

That a new bud thus constitutes each joint of the stem of wheat, and other grasses, is further evinced; first, by the existence of a leaf at each joint without a lateral bud in its axilla, as occurs in other vegetables. Secondly, because for the nourishment of this new leaf-bud a reservoir of sweet-juice is prepared in the new joint; as in the bulbs of many plants. And thirdly, because the lower leaf dies, and the sweet juice is absorbed, as the upper leaf becomes vegete. Hence we acquire the knowledge of the use of this reservoir of sugar in the vegetable economy, which supplies so much agreeable and salutary

tary nourishment to mankind from the cultivation of the sugar-cane. See No. 1. 6. and No. 3. 7. of this Section.

The analogy between the buds of plants and the adherent lateral progeny of some insects, as of the polypus, and tenia, or tape-worm, and volvox, was mentioned in Sect. VII. 1. 4. But the circumstance of the successive production of leaf-buds and leaf-bulbs previous to the production of flower-buds or flower-bulbs is wonderfully analogous to the generation of the aphis, which rising from an egg in the spring after casting its skin once or twice produces a living progeny without amatorial copulation; and this offspring produces others by this solitary propagation till the tenth generation; then a sexual progeny of males and females is produced, and eggs are laid in the autumn from their amatorial intercourse. Encycloped. Britan. Amœnitat. Academ. Vol. VII. by A. T. Bladh. See Sect. XIV. 3. 2. Thus this insect from the egg requires to be reproduced many times by solitary propagation before it becomes sufficiently perfect to generate a sexual offspring like the buds and bulbs from seeds above mentioned. And it is probable, that the polypus of our stagnant waters, which produces a lateral offspring in the summer, I suppose by solitary propagation, may produce males and females, and generate eggs in consequence in the autumn for their reproduction in the ensuing spring.

To this may be added the great change, which many insects and even larger animals undergo either in strength or form, before they acquire the power of feminal reproduction. As the silk-worm changes into a butterfly apparently for the purpose of generation only, as it then performs this office and dies. Other caterpillars change their form likewise into butterflies, and at the same time change their kind of food, which was the green foliage of vegetables before this transformation; but now consists solely of honey. And lastly, the gnat and musquito change at the same time both their forms, their food, and their element; and thus acquire higher animation apparently for the purpose of sexual reproduction.

2. The

2. The manner of the production of herbaceous plants from their various perennial roots wants further investigation, as their analogy is not yet clearly ascertained. I this autumn dissected two large roots of the onion or leek kind, which were in full flower; the stem of each of them was embraced by the cylindrical pedicles of six or seven concentric leaves; but the stem itself arose from the center between three large new bulbs in one of them, and between two in the other. All of which grew from the same caudex, but the central flower-stem was wrapped at its bottom in one membrane only, which separated it from the new bulbs in its vicinity.

A large root of a young onion, which grew from seed sown in the spring, was at the same time dissected by stripping off the leaves, and their fleshy bases, one after another, till two buds were visible in the center of the fleshy bases of the concentric leaves, which formed the bulb. These two bulbs were evidently formed and nourished on the caudex by the stem, and its six or seven concentric cylindrical leaves; and will, I suppose, separate in the spring, as they rise up, and produce each of them a flower with two or three new bulbs at the base of it, as described in the above paragraph.

Or from the different size and apparent greater maturity of the central bulb, and the secondary bulb being between the innermost and the second circular fleshy membrane, I suppose in these roots of onion, like the tulip-roots before spoken of, that the central bulb alone may produce a flower in the next summer; and that the lateral bulb or bulbs will produce only stronger and more mature leaf-bulbs, which will in the succeeding summer bear a flower or sexual progeny.

The caudex, or central part of the bulb, from which the root-fibres descend, and the leaves ascend, lies above the knot in the orchis morio; and the parent-root shrivels up and dies, as the young one increases. The flower of this plant does not ripen its seeds in this climate; it might be otherwise worth cultivation for the use of the

new roots ; which when scalded and peeled, are said to be the salep of the shops. It is asserted by one of the Linnean school in the Amœn. Academ. that if the new root be pinched off, the seeds on the old one will ripen, and become prolific.

In the tulip the caudex lies below the bulb, from whence proceed the fibrous roots and the new bulbs ; the root after it has flowered dies like the orchis root ; for the stem of the last year's tulip lies on the outside, and not in the center of the new bulb. In the tulip-root, dissected in the early spring, just before it begins to shoot, a perfect flower is seen in its center ; and between the first and second coat the large next year's bulb is, I believe, produced ; between the second and third coat, and between this and the fourth coat, and perhaps further, other less and less bulbs are visible, all adjoining to the caudex at the bottom of the mother bulb ; and which I am told, require as many years, before they will flower, as the number of the coats with which they are covered ; and that the same different states of maturity probably obtain in the buds round the shoots of many fruit-trees, the central one of which will produce flowers the next year as on the spurs of apple-trees ; while those beneath it require more or fewer years, before they become sufficiently mature to produce organs of sexual generation ; an important secret in the management of fruit-trees.

The hyacinth-root differs from the tulip-root ; for, as I am informed, the stem of the last year's flower is always found in the center of the root, as in the onions above described ; and that the new offsets arise from the caudex below this bulb, and not between any of the concentric coats of it, except the two external ones. On this account the central part is liable by its decay to destroy the flower-bud, if not taken out of the earth, when the leaves die ; and hence some florists believe, that these roots perish naturally in five or seven years, after they have flowered, but that the tulip-root never dies from age.

In

In a few roots of hyacinths, which I this day examined, September 1, the stem of one, which had apparently flowered in the summer, was perfectly decayed in the center of many new bulbs. In another bulb of less size and compact, which I supposed had not born a flower, I found a central flower-bud inclosed in many concentric fleshy bases of former leaves, like an onion in the autumn, which had been sown in the preceding spring. And concluded from hence, that the hyacinth-root dies annually or biennially like the onion, leaving behind it a succession of leaf-bulbs or of flower-bulbs.

The caudex and claw-like roots of the ranunculus cultivated by florists dies I believe annually, after having put forth a circle of new claws from the upper part of it round the bottom of the perishing flower-stem. Hence the claws of the old root, which became shrivelled, as the flower advanced, in the autumn disappear; and the decayed part of the old caudex is seen beneath the new claw-like roots, which I suppose has given occasion to some inaccurate observers to believe, that the old stem in this and some other perennial herbaceous plants was drawn downwards by the new root fibres; while the bulbs of the iris have been supposed to have been pushed upwards, like the lamb-like barometz, by the resistance of the soil to the elongation of the root-fibres; which last seems to be a much more probable idea than the former.

From these observations it appears, that the concentric leaves, which incircle the stems of bulb-rooted plants, are the lungs to the caudex, as one or more leaves are to the bud of a tree; and that the caudex with these leaves, and the root-fibres, constitute a vegetable being; which produces a viviparous progeny of new leaf-bulbs, or a seminiferous progeny in flower-bulbs, with a magazine of nutriment in the fleshy base of each leaf; and that the tulip produces only leaf-bulbs for four or five years from the seed, and then but one flower-bulb with many leaf-bulbs annually. But that the onion-kind, *allium*, generates two or three flower-bulbs in the first summer from

the seed ; which produce flowers and other leaf-bulbs in the second summer from the seed. And lastly, that it is probable, that all bulbous roots, like the buds of deciduous trees, and perhaps of evergreen ones also, are properly speaking biennial plants, as they rise in one summer and perish in the next.

3. In tulip-roots, which have been planted too deep in the earth, and in onion-roots, a vegetable cord, or process, is sometimes seen about an inch long to arise from the caudex beneath the bases of the cylindrical leaves, and to form a new bulb. Similar to this appears the natural growth of the roots of potatoes ; a spermatic cord arises from the old root, after the leaves are expanded in the air, to oxygenate the vegetable blood, and a new tuberous or bulbous root is thus generated.

This mode of producing distant roots is exactly resembled above ground by the wires of strawberries ; which may be called spermatic cords, which deposit a new vegetable being on the earth, and support it like a bud on a tree, till it can strike roots into the soil, and elevate leaves into the air. The final cause of the length of these subterraneous and aerial spermatic cords is evidently the design of placing their roots at a convenient distance from their parent plants ; that they may not incommode each other, but may both of them more readily acquire nutritious juices from the earth, and the ventilation and sunshine of the atmosphere.

These embryo vegetables in the various bulbous and tuberous roots are in very different states of maturity, as in the buds of different trees ; thus in the potatoe the corculum or plumula of the new plant only is visible, surrounded with a farinaceous nutriment, as in many seeds ; whereas in the tulip and hyacinth the flower of the succeeding year is discernible, as in the bud of the horse-chestnut.

As the ripening of the seed of some bulbous-rooted plants is forwarded by destroying the new bulbs, as in orchis ; and the flowering bulbs of other plants are made stronger by raising them out of the earth,

earth, and taking away the leaf-bulbs, which furround them on the same caudex; as in the customary management of tulip-roots, and hyacinth-roots by the florists; I was led to suspect, that pinching off the flowers of potatoes two or three times might increase the size or quantity of the roots; as the nourishment derived from the vegetable blood to the flowers and seeds might thus be directed to enlarge the roots, and thus lay up more nutriment for the future plants. This idea I mentioned to an ingenious Lady, who acquainted me a few months afterwards, that on a few roots she had made this experiment with apparent advantage.

4. The bulbous and tuberous roots of plants are a lateral or paternal progeny like the buds of trees, and therefore exactly resemble the parent plant, as mentioned in Sect. III. 2. 1. and on this account may be liable to be affected by hereditary diseases, and thus to become unhealthy; whence the canker is supposed to arise in those apple-trees, which have for a century or two been propagated by grafting; and the curled leaf in potatoes, which have been too long propagated by their bulbs; and the barrenness of hautbois strawberries, which have too long been propagated by wires; all which diseases are believed not to happen in these plants, if they have recently been raised from seed, but want further observations to authenticate the facts.

But there exists a set of bulbs, which seem to be formed by amatorial or feminal generation, and not by the lateral or paternal generation, and would therefore seem to be a viviparous sexual progeny. These are produced on the flower-stem in the place of seeds; and in process of time fall off, and take root in the earth, as is agreeably seen in the *polygonum viviparum*, viviparous bistort, and the magical onion, *allium magicum*, and the leek, *allium sativum*. A curious question here occurs, whether the plants from these bulbs are liable exactly to resemble their parents? and whether they would be liable to hereditary diseases from a long cultivation of them in succession, as is supposed to happen to those mentioned above?

Though

Though a perfect flower precedes the product of some summit-bulbs, as I believe in the lower part of the spike of the *polygonum viviparum*; yet I suspect, that the summit-bulbs of *allium magicum*, are exactly similar to the bulbs, which are produced at their roots; because on cutting one of them horizontally into two hemispheres this morning, September 10, I observed three young bulbs inclosed in the concentric fleshy membranes of the summit-bulb in the following manner; five thick fleshy concentric coats of the general summit-bulb being taken away, there appeared one single naked small bulb; and on the sixth coat being removed, two other bulbs became visible, which were included in it. Whence it seems, that these stem-bulbs are as forward as those of the root, and probably are in every respect similar; and that the bractes or floral-leaves, which in seed-bearing plants secrete or prepare a nourishment for the seed, and pericarp of the flower, acquire in these bulbiferous onions and leeks a new office, and prepare a magazine of nourishment in the concentric membranes, which surround their summit-bulbs; and these may be esteemed therefore a sexual viviparous progeny of vegetables, as buds are a lateral viviparous progeny.

5. The roots of trees so resemble their branches, that subterraneous buds are frequently produced upon them, which resemble the parent-tree. The bark of the root likewise so resembles the bark of the branches, that it is not uncommon to ingraft with success on roots taken out of the earth and replanted; as the robinia on the root of the acacia, and any other apples on the roots or the suckers of bur-apples or of codlings; which may be done earlier in the vernal months, as being less liable to injury from frosty nights; and it is probable, that budding or inoculating may be performed in the same manner on the roots at midsummer, as on the branches.

The roots of those plants, which are otherwise not easily propagated, will shoot up buds, if a part of them next to the plant be half cut through, or raised out of the ground, and exposed to the air; as

in pyramidal campanula, and geranium lobatum ; and after a time the root may be separated from the stock, and many new plants may be this way produced.

These root-buds, or suckers, are generally produced near the trunk of the tree, before the root descends much beneath the soil ; but in some trees, as the elm, ulmus, and acer, maple, whose roots spread far horizontally, and near the surface of the earth, they are generated at a great distance from the parent tree ; because the new scion can thus soon acquire the influence of the atmosphere on its expanding foliage. These root-scions from apple-trees are frequently used in vegetable nurseries for the purpose of ingrafting upon, and are termed paradise-stocks by some gardeners ; but are not liable to the canker like the grafts from those old apple-trees, which have been in fashion above a century ; as these root-scions resemble the trunk of the tree, which produces them, not the ingrafted head of it ; and thus may not have been many years from the state of a seedling vegetable.

Similar to these root-scions of trees it is probable, that the root-buds of perennial herbaceous plants are produced ; which have divaricated, or fibrous-roots, and whose summits perish in the winter. For many years the root thickens by an annual new bark being induced over the old one, exactly as in the trunks and roots of trees.

As these roots increase in size, the central part, I suppose, changes like the internal wood of a tree, and ceases to possess vegetable life ; and in process of time is liable to decay. On this account these perennial roots are not so valuable for the purposes of medicine or diet, or mechanic arts, either before or after they have passed a determinate age ; as the bark of the root changes annually into a kind of alburnum, and then into a kind of wood, and lastly, is liable to decay, as occurs in the roots of rheum palmatum, when they are seven or more years old. See Sect. XVII. 2. 1. This decay of the central part of the root, which happens annually to some plants, and is surrounded with new buds and their root-fibres, exhibits the appearance of the
lower

lower end of the root having been chopped, or bitten off, to some fanciful botanists; as in *plantago major*, and *valerian*; and has hence given to *scabiosa succisa* the name of devil's-bit, *morfus diaboli*.

6. The bulbs already mentioned, as those of tulips, hyacinths, and onions, are properly the winter-cradles, or hybernacula, of the young plants, whether in their leaf-bulb or flower-bulb state; and are furnished with a magazine or reservoir of nourishment for the growing embryos, as appears in the squil, *scilla maritima*, which vegetates from this source of nutriment in the druggists shops. But there are other roots termed tuberous roots, as of turnep and carrot, which consist solely of a large reservoir of nutriment for the growth and nourishment of the rising stem and future seeds; whether these are produced in the same year, as occurs, when the seeds are sown early in the spring; or when their vegetation is stopped by the cold of winter, and proceeds again in the ensuing spring; as generally occurs to our turneps, the roots of which I am well informed may be much enlarged by transplantation. See Sect. XII. 6.

In these plants the leaves, by exposing the vegetable blood to the influence of the air, prepare it for the secretion of nutriment in their knobby roots; in the same manner as nourishment is produced and reserved in the concentric fleshy bases of the leaves of onions; and in these plants, as in the onion kind, the leaves, which surround the base of the new stems, wither and die; as the new buds, or bulbs, put forth leaves of their own for the purpose of oxygenating their blood. Thus it appears, that the stem and flower of the onion, or carrot, or turnep, is a new plant, not arising immediately from the seed which was sown, but from the leaf-root or leaf-knob, if it may be so called, which preceded the production of the flower-bud, or flower-stem, exactly as the flower or ear of wheat, which was shewn in Sect. IX. 3. 1. to have three or four successive leaf-buds preceding the flower-bud.

From these observations may we conclude, that no flower-bud or
flower-

flower-bulb is ever produced from a seed, without the previous interposition of one or more leaf-buds or leaf-bulbs? and that those flower-buds or flower-bulbs are either produced in one generation after sowing the seed, as the flower-bulbs of onions, which are generated and nourished at the bases of the concentric cylindrical leaves of the preceding leaf-plant, which arose from the seed; or as the stems and flower-buds of the carrot and turnep, which are generated and nourished at the base of the concentric leaves of the preceding leaf-plant. Or secondly, that they are produced in one summer, though after several generations from the seed; as the three or four joints of the stem of wheat, and other grasses, which are generated and nourished in succession in the bosoms of four or five cylindrical leaves, one at each joint; which also probably obtains in all other vegetables, which are supported by hollow stems divided by joints, and furnished with leaves at these stem-joints with or without branches, as tragopogon or picris. In these plants, where there are no branches, there is simply a new central bud; and two or more lateral new buds beside the central one, where there are branches.

Or lastly, where the leaf-buds or leaf-bulbs, which are produced from seeds, succeed each other for some years, before they arrive at sufficient maturity to produce sexual organs, or generate a flower, as in the bulbs of tulips, and hyacinths, and the buds of trees. Whence we at length acquire a distinct idea, why seedling apple-trees are ten or twelve years before they bear fruit; though the buds or shoots taken from a tree, which already has born fruit, and ingrafted even on a young seedling-tree, shall produce flowers in the first or second year; as these buds have already acquired that state of perfection or maturity, which is necessary to the production of sexual or feminal generation: and as it therefore possesses the age of puberty, or the maturity of the tree; we may suspect, that it will sooner acquire the hereditary diseases consequent to too long unmixed suc-

cessive generations, a piece of very important knowledge to the planters of orchards; which they owe to the observation of Mr. Knight, as mentioned in Sect. VII. 1. 3.

Hence in many plants produced from seeds, perhaps in all, one or more leaf-buds precede the flower-bud; and I suppose generally, if not always, a magazine of aliment is formed at the bases of the leaves, or in the roots, for the nutriment of the succeeding leaf-bud or flower-bud, of which it is the parent.

Thus in the carrot and turnep the first leaves constitute the lungs of the new vegetable being, which generates the succeeding flower-stem, and secretes or deposits for it a magazine of aliment, which forms the tuberous root: and then this first plant from the seed and its leaves or lungs perish; and the root gradually shrivels up, as it is absorbed by the new flower-stem. In many plants these first or root-leaves differ in form from those of the succeeding stem, as in palmated rhubarb, and in *campanula rotundifolia*, which is so called from the round form of the leaves of this first leaf-bud, or root-plant, which precedes the flower-stem.

7. One great advantage of Mr. Tull's horse-hoeing husbandry, in which the earth near the rows of wheat is alternately turned from and to them during the vernal months, has been supposed to arise from some fibres of the roots being thus cut off, and new stems shooting up at the ends of those which remain; but the real cause of the production of the new stems is from the accumulation of earth above the first joint of the young wheat-plant; from which the new buds spring out, generated and nourished by the caudex of the leaf, which surrounds that joint, and which afterwards withers; this important circumstance is shewn by the annexed delineation of a transplanted wheat-plant.

The plant of wheat was taken from a corn-field in the spring, and then consisted first of the root immediately proceeding from the
feed

seed *a*, which has been called the feminal root ; and secondly, of the root, which was then near the surface of the ground *b*, which has been called the coronal root, was furnished with a stem and leaf, *c*, *d*, and with a secondary stem, or root-scion, *e*, *f*. This wheat-plant consisting of only two stems was replanted in my garden, and purposely buried so deep as to cover the two or three first joints of both the stems beneath the soil ; that is as high as the letter *f*, where the secondary stem was purposely cut off.

On taking up this plant with some others on September 24, it had assumed the form here delineated. The primary stem, *c*, *g*, had shot out no new roots from the joint *g*, which I suppose to have happened from its being too far advanced when replanted ; as many other stems of other wheat-plants, which had not been obtruncated, had nevertheless put forth one or more lateral stems or root-scions at the second or third joints, which on transplantation had been covered with the soil.

But the obtruncated stem, *e*, *f*, had generated a new root-scion at *b*, like the first shoot from the seed at *a* ; which had produced other new stems, as it approached nearer the surface of the earth at *i* ; and as these advanced into the air, and formed their leaves, other new root-scions were generated at *k* and *l*. Whence it appears, that by decapitation, and a deeper immersion in the ground, a secondary stem in this plant became multiplied into five ; all which produced perfect ears of corn ; and in other roots, which I had planted in a similar manner, the increase was much greater : and especially where one or more of the primary or secondary stems had been decapitated.

If a grain of wheat be dropped on the surface of the earth, and suffered to shoot down its roots, and to raise its stem, which is the process of nature, I suppose but one stem would be produced ; as the first knot or joint of it would not be covered with earth, and could

not therefore shoot down new roots ; which are necessary in these plants to the production of new stems, which are not branches but suckers or root-scions.

But if the grain be buried an inch deep in the earth, a shoot rises from the roots, which issue from the seed, which is an elongation of the caudex, and puts forth a leaf in contact with the surface of the earth ; this leaf and stem constitute the primary plant, and generate new buds, which put forth new roots descending into the earth ; and thus three or four or more suckers, or new plants, arise round the original one, which was contained in the seed : hence the appearance of two roots, which some authors have named the feminal and coronal roots. The ingenious Mr. Tull seems himself to have been aware of this circumstance, as he says in his Husbandry, “ Late planted wheat sends out no root above the grain before spring, but is nourished all winter by a single thread proceeding from the grain up to the surface.”

This explains the prodigious multiplication of the stems of wheat, which may be produced by transplanting it three or four times in the summer, autumn, and ensuing spring ; for if it be so managed, that a second joint of each young stem be buried in the soil, or brought even into contact with it, so that new roots may strike down into the earth ; the caudex of the leaf, which surrounds this joint, will generate many new buds, which will thus become suckers, or root-scions, and rival their parent ; and may be again transplanted or earthed up three or four times with wonderful increase. Mr. Charles Miller of Cambridge sowed some wheat on the second of June 1766, and on the eighth of August one plant was taken up and separated into eighteen parts and replanted ; these plants were again taken up and divided between the middle of September and the middle of October, and again planted separately to stand the winter, and this second division produced sixty-seven plants. They were again taken up, and divided between the middle of March and the middle of April, and

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produced

produced five hundred plants. The number of ears thus produced from one grain of wheat was 21109, which measured three pecks and three quarters of corn, weighed forty-seven pounds seven ounces, and were estimated at 576840 grains! *Philos. Transf. Vol. LVIII. p. 203. See Sect. XII. 6.*

Nor is this unsupported by the analogy of other vegetables, in which new roots are liable to shoot in great abundance from their joints either alone or along with new buds, if a proper degree of moisture is presented to them. Thus if the stem of a potatoe be laid down upon the earth, and covered with soil over the first joint, a new series of roots will be protruded from that joint; and afterwards another series of roots from the second joint, if managed in the same manner; and it is asserted that this will occur even if the potatoe stems are taken out of the ground, when they are six or eight inches high, and deprived of all their young roots, and transplanted, so as to cover one or two joints, and that a great crop has been thus produced.

The rapid growth of some grasses, and of some species of the convolvulus, and of colt's-foot, is well known, and very troublesome in many situations. Of these very minute parts of the jointed root, when cut from the parent, elongate themselves, and shoot up new plants. From the very numerous divisions of the wheat-root described by Mr. Miller, it may be suspected that something similar to this must have happened, which further observations must determine.

Vines also are thus liable to shoot out roots at their joints, and fig-trees, when covered only with a shred of cloth in nailing them to a wall, if it be accidentally kept moist. And there is an apple-tree, which is called a burr-apple, because it puts out roundish protuberances or excrescences of the bark like a burr, which if the branch be bent down, or even torn off, and set in the moist earth, will

will immediately strike out roots, as I am told, and become a tree similar to the parent.

In the same manner I have been informed that if a circular ring of the bark be cut off from many trees and shrubs, which are otherwise difficult to propagate, and earth be put round the branch thus decorticated a few inches above and below the wounded part, by means of a garden-pot previously broken longitudinally, and bound together round the branch, that roots will shoot from the upper lip of the wound; and in a little time the branch may be safely cut off below the garden-pot, and planted with success.

When a few inches of the end of a branch are cut off in the spring, as is common in pruning wall-trees, new buds are produced near the extremity, which remains; or those, which did exist, grow with greater vigour; as they obtain some of that nourishment, which should have supported the buds, which were cut off. The same occurs in respect to the suckers or root-scions of those trees, which produce them, as of elm-trees, and of some apple-trees; if many of the branches be cut away, the suckers or root-scions become more numerous, or more vigorous.

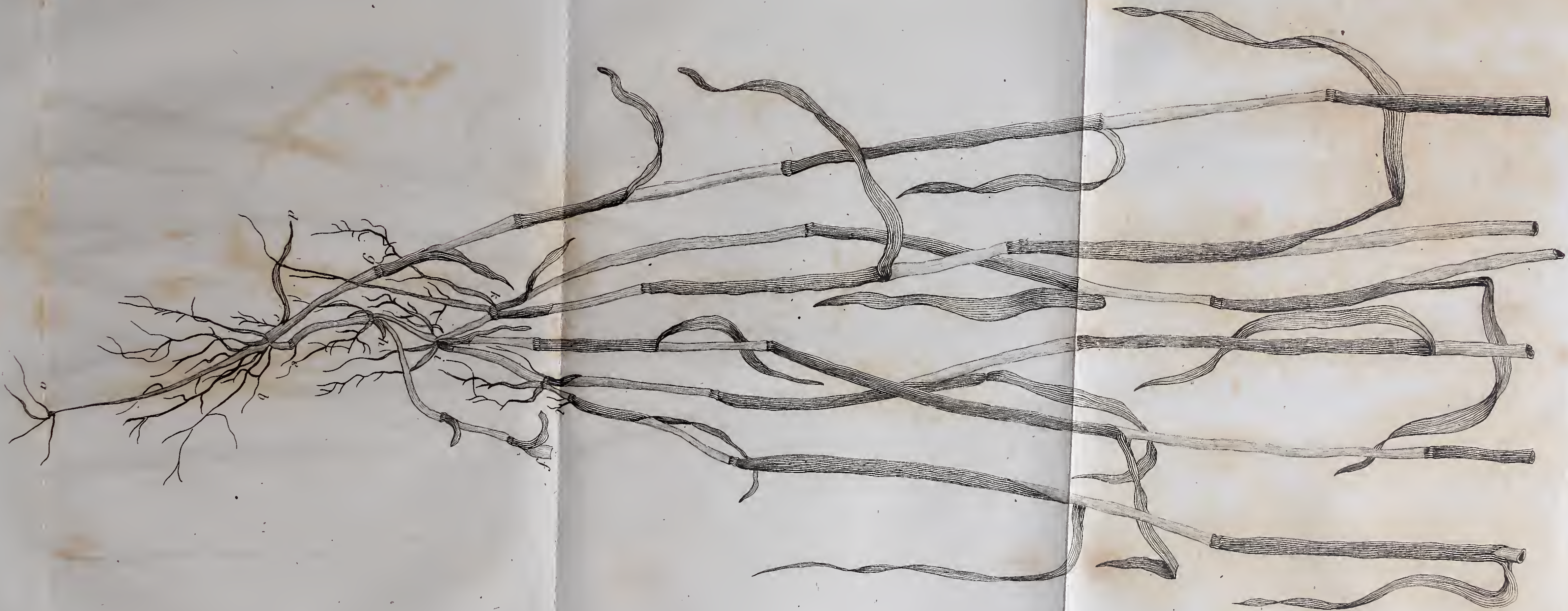
This explains the use of a practice among many farmers of eating down a forward crop of wheat in the spring with sheep. In this case the central or upright stem of the wheat is decapitated, and many lateral ones, or root-scions, as above described, become generated, or grow with greater vigour; acquiring additional nourishment from the joint, which was to have been expended in the growth of the central stem; and which appears so distinctly in the preceding figure of a transplanted wheat-plant, which nevertheless in crops, which are not too forward, may be very injurious, as spoken of in Sect. XVI. 2. 3.

Thus the figure above alluded to explains four important circumstances in the cultivation of grains, that of earthing up the rows in

PLATE IV.

PLATE IV.

Represents a transplanted root of wheat described in Sect. IX. 3. 7. *a* the feminal root, *b* the coronal root, *a b* the elongated caudex, *c g* the first stem, *c d* the first leaf, *e f* a secondary stem. All these existed before transplantation. The secondary stem was then cut off at *f*, and the plant was buried in the soil as deep as the letter *f*, where it was cut off. Afterwards the stem, which was lopped, had put forth a new caudex or root-scion at *b*; which had produced three new stems at *i*; and other new ones, as it approached nearer the surface, at *k* and *l*. As these leaves advanced into the air, the latter new stems were produced by the caudexes of them.



spring by Mr. Tull's horse-hoe; that of eating down the first stems of forward crops by sheep; that of transplanting the roots deeper in the soil; and that of sowing the seed an inch or two beneath the surface. For an account of the drill husbandry now practised by Mr. Coke of Holkham in Norfolk, see Sect. XVI. 2. 2.

S E C T. X.

MANURES, OR THE FOOD OF PLANTS.

- I. 1. *The CHYLE of all animals is similar. It consists of water, sugar, mucilage, oil, with carbon, phosphorus, and calcareous earth. The SAP-JUICE of vegetables consists of water, sugar, mucilage, with carbon, phosphorus, and calcareous earth.* 2. *Food of young animals, of adult animals. Power of digestion. Production of sugar by digestion.* 3. *Food of young vegetables. Production of sugar by germination.* 4. *Food of adult plants from the spontaneous decomposition of vegetable and animal bodies, or from water and air alone. They possess low heat and cold blood like winter-sleeping animals. Distinction between animals and vegetables.* II. 1. *AIR. Oxygen in air, in water, united with heat, and light.* 2. *Forms all acids.* 3. *Metallic oxydes.* 4. *The bases of all acids are insoluble in water.* 5. *Carbonic acid gas from fermentation. In its fluid state.* 6. *Aqueous acid.* 7. *Oxygen in vegetable perspiration.* 8. *Plants sprinkled with oxygenated water. Oxygen gas applied near their roots.* 9. *Azote or nitrogen is found in vegetables. Produces nitre and ammoniac* III. 1. *WATER. Its large quantity in plants.* 2. *Use of their great perspiration.* 3. *Water becomes decomposed in plants, and is hyper-oxygenated.* 4. *Gives lubricity, fluidity, and solution.* 5. *Irrigation of the soil brings other manures.* 6. *Penetrability of the soil from irrigation. Sow and reap early in wet soils.* 7. *Hasty showers are injurious. Hills should be ploughed horizontally. Use of ridges and furrows. Surface of air greater.* 8. *Evaporation produces cold. Uses of coping-stones on fruit-walls.* 9. *Production of foliage requires more moisture than that of seeds. Frost in Scotland ripens the corn.* 10. *Lime and dung-hills attract water. Steam used in hot-houses. Much water in the atmosphere.* IV. 1. *CARBON is an universal material in the atmosphere.* 2. *In limestone.* 3. *In black earth, morasses, loam. Carbon combines with putrid exhalations.* 4. *United with oxygen is soluble in water. Lime combines with water. Emits heat. Is broken into powder by steam. Should be slaked before it is used in agriculture. Better slaked with hot water.*

Attracts

Attracts the carbonic acid, and in consequence the water, of the atmosphere. 5. Carbonic acid subsides on the earth in the air. 6. United with calcareous earth is soluble in water, and absorbed by vegetables. 7. An experiment in which carbon and lime form an hepar, and thus become soluble in water. 8. Vegetable roots absorb carbonic acid from limestone in its fluid, not its gaseous state. 9. Carbon exists in sugar and mucilage, which are absorbed undecomposed. V. PHOSPHORUS is a simple substance. Appears in rotten wood. In putrescent flesh and fish. 2. Exists in all vegetable and animal matter, as seen in Homberg's pyrophorus, and in Kunkel's phosphorus. 3. And in all calcareous earth, as in oyster-shells, limestone, gypsum, fluor. 4. Hence the use of calcareous earth in agriculture. 5. Shells become limestone by attracting carbonic acid from the air. Mountains of calcareous phosphorus. Limestone should be burnt in close vessels. 6. The hardness of bones owing to phosphoric acid, and perhaps of ligneous fibres. VI. 1. LIME with carbon may make an hepar carbonis soluble in water. 2. Unites with carbonic acid, and renders it soluble in its fluid not its gaseous state. Water from springs is preferable to that from rivers for flooding lands. 3. Lime unites with phosphorus, and renders it soluble in water. Unites also with phosphoric acid. Whence crab-fish renew their shells, and snails repair and enlarge theirs. 4. Lime unites with oil and mucilage, and may thence become nutritious. It decomposes soap, and constitutes a part of animals and vegetables. 5. Lime destroys the cohesion of dead vegetables. Of recent ones by combustion. Attracts moisture from the air and earth. Makes clay less adhesive. Unites with acids of vitriol and of nitre. Kills insects. 6. One limestone twenty miles long and ten broad. Lime not of use on wet land, nor always on all calcareous soils. 7. Lime both forwards the ripening and meliorates and increases wheat and grass by supplying nutriment. 8. Gypsum, fluor, bone ashes. Breeds lime is half magnesia. VII. 1. CLAY is too adhesive. Becomes more solid by frost. 2. Effervesces in the air. Acquires oxygen. So iron, manganese, zinc. Raddle used as manure. 3. Granite acquires oxygen. Granites and dry clay have a smell when breathed on. Marl crumbles in the air. Burnt clay acquires oxygen and burnt lead. 4. Burnt clay promotes the generation of nitre. Use of paring and burning. 5. Burnt clay decomposes marine salt. Use of sea-salt in manure. 6. Would phosphat of lime combine with clay, or bone-ashes? 7. Cohesion of clay overcome by air. By roots of strong plants. By carbonic acid from leaves in the shade. By dung-hill water. By lime. 8. Aluminous clays how to correct. By wood-ashes, soap-suds, lime, magnesia. VIII. 1. SPON-

TANEOUS MANURES. *Saccharine fermentation is a chemical process. Exists beneath the soil.* 2. *Vinous fermentation. Carbon and oxygen in a fluid state. Heat of bark-beds. Hay-stacks take fire.* 3. *Putrefaction decomposes water.* 4. *Produces nitre, whose loose oxygen promotes vegetation.* 5. *Sow soon after the plough.* IX. CHEMICAL MANURES. 1. *Sugar and mucilage absorbed undecomposed.* 2. *Heat destroys life in seeds, fruits, roots. Potatoes dried on a malt-kiln. Cooked in steam hotter than boiling water. Papin's digester.* 4. *Trituration of wood, straw, hay, for food in times of scarcity; of bones, chalk, bricks, ocbres, calamy for manures.* X. INSECT-MANURE. *Cultivated countries increase in fertility. Some have decreased. Calcareous strata from shells. Those above them from vegetables and animals. The former can live on air and water, not the latter.* 2. *Crops ploughed in for manure.* 3. *Insects increase manure. Water from dungbills.* 4. *Fish.* XI. PRESERVATION OF MANURES. *Rains wash manure into the sea. Snow floods less injurious. Hills should be ploughed horizontally.* 2. *Common shores.* 3. *Burial grounds.* 4. *Wood-fuel.* 5. *Fermentation requires air, water, heat. Manure should be turned over and mixed with lime.* 6. *Pig-troughs, soap-suds.* 7. *Weeds, leaves, water-plants.* 8. *Peat.* XII. APPLICATION OF MANURES. 1. *In powder for top-dressing. In straw for clay-fields.* 2. *In fields when the corn is sowed. On grass-lands in the spring, not in the autumn.* 3. *Cover dung-heaps with soil. Gather cow-dung from the grass.* 4. *What manures are most nutritive. Flesh, horn, woollen rags, meal, sugar, oil.*

I. 1. The various substances, which constitute animal bodies, or which are found in the cavities of them, are composed from simpler elements by the processes of digestion, and sanguification, and secretion; for it is well known, that even milk, which so much resembles the chyle of animals, is not absorbed by the lacteals without its being previously coagulated, and again dissolved in the stomach by the power of digestion.

Hence it happens, that the chyle of all animals, and from every kind of food which they take into their stomachs, is very similar; and like milk consists of water, sugar, mucilage, and oil; the last of which

which not being soluble in water, but only miscible with it, gives it its opaque white colour.

But though the chyle from different kinds of aliment is so similar, and all the various constituent parts of animal bodies are ultimately produced from the chyle by sanguification and secretion, yet it happens, that some kinds of aliment possess a greater quantity of these particles, which make chyle, than other kinds of aliment. Such materials for instance as already contain much sugar, mucilage, and oil, as the flesh of dead animals, or the fruits and seeds of vegetables.

Besides the water, sugar, mucilage, and oil, which exist in chyle, there may be other materials, which are invisible from their perfect solution in water, either alone or when converted into acids by the addition of oxygen; as carbon, phosphorus, calcareous earth, marine and ammoniacal salts; though it is more probable, that the two last are formed and secreted by animal processes, as well as selected by their absorbent roots, as they are more compounded bodies than the former.

Similar to this chyle of animals the sap-juice, which is absorbed from the earth by the roots of plants, constitutes their nourishment, and consists of water, sugar, and mucilage, with other transparent solutions, as of carbon, phosphorus, and calcareous earth. And though it has been proved by the experiments of some philosophers, that vegetables can extract or compose all these substances from air and water alone; yet some materials contribute more to the production of this vegetable chyle or sap-juice than others, such as the recrements of dead vegetable and animal substances.

2. If any one should ask, what is the food of animals? I should answer, that in the most early state of animal life the embryo lives on a mucilaginous fluid, with which it is surrounded, whether in the egg or womb: that in its infant state the young animal is sustained by milk, which its stomach converts into chyle.

In their adult state animals are sustained by other vegetable or animal substances taken into their stomachs, which are there converted into chyle partly by a chemical, and partly by an animal process; as by a mixture of gastric juice with water and heat, some of these recrements of organic nature are decomposed, either into their simpler component parts, or sometimes even into their elements; while other parts of them are only rendered soluble or miscible with water; and are then drank up by the absorbents of the stomach and intestines.

In this process of digestion much sugar is produced, which is probably immediately selected and drank up by the numerous mouths of the lacteals, or lymphatics; to which it is presented by the vermicular or peristaltic motions of the stomach and intestines. And as this ready selection and absorption of the sugar, as soon as it is formed, prevents it from passing into the vinous or acetous fermentation; it is probable that from the want of such a means of separating saccharine matter, as soon as it is formed, chemistry has not yet been able to produce sugar from its elements without the assistance of animal digestion, or vegetable germination; as further spoken of in No. 8. 1. of this section.

In this process of digestion, I believe, a great part of the water, sugar, mucilage, and oil, which exist in vegetable and animal recrements, are not decomposed into their elements, but absorbed by being soluble or miscible with water; the carbon, and the phosphorus, and the hydrogen, are also I suppose dissolved in the other fluids by means of oxygen, and form a part of the chyle, without their being converted into gases; for when this happens to any excess in respect to carbon, it escapes from the stomach in eructations; and the same occurs to the inflammable air or hydrogen, if a part of the water becomes decomposed in the intestines; which, if it be not absorbed by its solution in other fluids, but acquires a gaseous state, is liable to escape below; though both these gases seem occasionally

to revert to a fluid state from their aerial one in the stomach or intestines, and to be then absorbable by the lacteals or lymphatics.

3. What then is the food of vegetables? the embryo plant in the seed or fruit is surrounded with saccharine, mucilaginous, and oily materials, like the animal fetus in the egg or uterus, which it absorbs, and converts into nutriment; while the embryo buds of deciduous trees, which is another infantine state of vegetables, are supplied with a saccharine and mucilaginous juice prepared for them at the time of their production, and deposited in the roots or sap-wood of their parent-trees; as in the vine, maple, and birch; which saccharine matter is soluble and miscible with the water of the surrounding earth in the subsequent spring, and is forcibly absorbed by their root-vessels, and expands their nascent foliage.

In their infantine state therefore there is a wonderful analogy between plants and animals; and it is particularly curious to observe in the process of converting barley into malt by the germination of the seed, that the meal of the barley is in part converted into sugar by the digestion of the young plant exactly as in the animal stomach. The wonderful effect of vegetable digestion in producing sugar may be deduced from the great product of the sugar-cane, and of the maple-tree in America, mentioned in Sect. III. 2. 3. and the wonderful effect of animal digestion in producing sugar appears in patients, who labour under diabetes. A man in the Infirmary of Stafford, who drank daily an immoderate quantity of beer, and who eat above twice the quantity of food that those in health consume, voided sixteen or eighteen pounds of water daily, from each pound of which above an ounce of coarse sugar was extracted by evaporation. *Zoonomia*, Vol. I. Sect. XXIX. 4. 9.

4. We now come to consider the food of adult plants; and in this consists the great and essential difference between the nutritive processes of animals and vegetables. The former are possessed of a stomach, by which they can in a few hours decompose the tender parts

of

of vegetable and animal substances by a chemical process within themselves, conducted in the heat of ninety-eight degrees, with a due quantity of water, and a perpetual agitation of the ingredients ; which both mixes them, and applies them to the mouths of the absorbent vessels, which surround them. Whereas a vegetable being having no stomach is necessitated to wait for the spontaneous decomposition of animal or vegetable recrements ; which is indeed continually going on in those soils, and climates, and in those seasons of the year, which are most friendly to vegetation ; but is in other situations, and in other seasons, a slow process in a degree of heat often as low as forty of Fahrenheit, (in which the reindeer moss, *moschus rangiferinus*, vegetates beneath the snow in Siberia,) and often without an adapted quantity of water to give a due fluidity, or any mechanical locomotion to present them to the absorbent mouths of their roots ; or in still worse situations adult vegetables are necessitated still more slowly to acquire or produce their nutritive juices from the simpler elements of air and water, with perhaps the solutions of carbonic acid and calcareous earth, and perhaps of some other matters, with which one or more of them abound.

But M. Haffenratz found, that the vegetation of those plants was imperfect, which had not been suffered to grow in contact with the earth ; as they never arrived at such maturity as to produce fruit ; and were found on analysis to contain a less portion of carbon, than other plants of the same kind. The experiments were tried on hyacinths, kidney-beans, and cresses.

Hence the other great difference, which exists between these two extensive kingdoms of nature, is, that the larger and warmer blooded animals certainly, and I suppose all the tribes of insects, and of colder blooded creatures also, can not exist long on air and water alone, except in their state of hibernal torpor. The nearest approach to this is however seen in some fevers, where water alone has been taken for a week or two, and yet the patient has recovered ; and there is a well
attested

attested account of a numerous caravan, which having lost their rout, or their provisions, are affirmed to have lived some weeks on gum arabic and water alone.

Vegetables on the contrary, as above mentioned, can exist, though in a feebler state, on water and air alone, with the carbonic acid, and perhaps other invisible solvents, which those elements unavoidably contain. This I suppose to be owing to the low degree of heat, which they produce internally, and to the slow circulation of their blood; from both which circumstances less nutriment is expended, as by animals which sleep in winter.

For the purpose of supplying adult vegetables with nourishment, we should first consider what kinds of matter are most prevalent or most necessary in their composition. Secondly, what of these substances they can absorb without previous decomposition. Lastly, how to expedite the decomposition of vegetable and animal substances on or in the soil, like the digestive processes in the stomachs of animals; we may thus become acquainted with the sources and the management of manures.

II. A I R.

1. Oxygen combined with heat constitutes that part of the atmosphere, which is perpetually necessary to animal and vegetable respiration; and a greater part of that water, which forms a principal portion of their organization; a few words may be therefore premised on these most important discoveries of modern chemistry.

This vital air, called oxygen gas, constitutes twenty-seven hundredth parts of the atmosphere; it is indispensably necessary to the existence of life, and of combustion, and forms the principal part of all acids; whence its name. The other seventy-three hundredth parts of the atmosphere consist of azote, which takes its name from its inutility to life in animal respiration; it is also called nitrogen, because it constitutes the basis of nitre.

Oxygen gas consists of oxygen and heat ; and when it unites with such bodies, as are capable of uniting with it, the heat is set at liberty, as in respiration and in combustion ; in both which processes an acid is produced by the combination of oxygen with some inflammable base. Hence vital air consists of oxygen dissolved in the fluid matter of heat ; but there is also another fluid, which seems to be combined with this solution of oxygen in heat, and that is light. For when oxygen becomes combined with charcoal, or with sulphur, or with phosphorus, both heat or light are set at liberty from these new combinations of oxygen ; which thus produce the carbonic, sulphuric, and phosphoric acids.

When these new combinations of oxygen are performed very slowly, the light is sometimes not visible, as in the heating of a dunghill ; in which process the oxygen in the cells or cavities of the hot-bed unites slowly with the carbon and phosphorus of the decomposing vegetable and animal matters ; but though much heat is given out, no light is seen. While on the contrary from rotten wood alone, or putrescent fish, when exposed to the atmosphere, much light is emitted, but not much sensible heat, owing perhaps simply to the combustion of the phosphorus, which they contain.

2. The products of these combinations of oxygen with other bodies may all of them be termed acids ; though in some the heat or light set at liberty converts these acid productions into gasses, as oxygen and charcoal form carbonic acid gas ; and in others it converts the new product into steam, which is condensible by cold, as the sulphuric acid from the combination of oxygen and sulphur ; and the phosphoric acid from oxygen and phosphorus.

3. Other combinations of oxygen with heavier substances are produced in the atmosphere without the separation of either sensible heat, or visible light ; as the union of oxygen with metallic bodies, as with that of manganese, with zinc, lead, iron, as in common ore of manganese, in lapis calaminaris, white calciform lead-ore, and the

red ochre of iron ; which have not obtained the name of acids, but are termed oxydes of those minerals.

4. Now it happens, that none of these bafes, which can combine with oxygen alone, are foluble in water, and therefore can not be imbibed by the abforbent veffels of vegetable roots, until they become acids ; and are perhaps then all of them in greater or lefs quantities foluble in water ; and are thence capable of being drank up by the abforbent veffels of vegetable roots, and conftitute a part of the food of plants.

5. When vegetable fubftances are decomposed by fermentation, there is a quick union of oxygen and carbon ; and this carbonic acid gas, called formerly fixed air, riles up in vapour, and flies away. But where this procefs goes on more flowly, as in a dung-hill lately turned over, or in black garden mould lately turned over, and thus expofed to the air ; much of which remains in the cells or cavities of the hotbed, or border ; this carbonic acid is flowly produced, and is abforbed by vegetable roots, I fuppofe in its fluid ftate, or diffolved in water, before it acquires fo much heat as to rife in the atmofphere in the form of gas.

This carbonic gas in its fluid ftate, or diffolved in water, not in its aerial or gaffeous ftate, is the principal food of plants ; as appears, becaufe their folid fibres confift principally of carbon, and their fluids of water.

6. Next to carbonic acid the aqueous acid, if it may be fo called, or water, feems to afford the principal food of vegetables ; as water confifts of oxygen and hydrogen, it is properly an acid, like all other combinations of oxygen ; and when abforbed by vegetable roots becomes in part decomposed in the circulation or fecretion of their juices ; the oxygen difappears, or contributes to form the vegetable acids ; and the hydrogen produces ammonia by its union with azote ; which may contribute to vegetable nutriment by its mixture with oils, and thus producing foaps, which become diffufible in water ; and alfo by

decomposing insoluble saline earths, as gypsum, or metallic salts, as vitriol of iron, and thus producing more soluble or innocuous salts. And which lastly forms a part of the various vegetable productions of sugar, honey, wax, resin, and other secretions.

7. There is a curious evolution of oxygen attends the perspiration of the leaves of plants, which is not known to attend that of animal lungs; and that is, that when vegetable leaves are exposed to the sun's light, they seem to give up oxygen gas; but in the dark they give up carbonic acid gas, like the breath of animals. It is probable that animal lungs might do the same, if they were exposed to the light; as perhaps might be subjected to experiment in the gills of fish, or by breathing through a tube into water in the sunshine.

In respiration as well as in combustion some light may possibly be given out as well as some heat from the combination of oxygen with some phlogistic base, as carbon or phosphorus; whence the production of carbonic and phosphoric acids in both animal and vegetable respiration. In most animals this quantity of light is probably too small to be perceived, if their bodies were transparent; but in the glow-worm of this country, and in the more luminous fire-flies of the tropical climates, I suspect the light to be emitted from their lungs in the act of respiration, which is a slow combustion.

8. Besides the use of oxygen in the respiration of vegetables, when applied to their leaves, as it is mixed in the atmosphere; it is believed by many to contribute much to their growth and nourishment in its combined state, when absorbed by their roots; and that by the decomposition of water in the vegetable system, when the hydrogen unites with carbon and produces oil, the oxygen becomes superfluous, and is in part exhaled, as further spoken of in Sect. XIII. 1. 2. Hence also some calciform ores, or metallic oxydes, as raddle, and calamine, and burnt clay, are supposed to be useful as manures, because they contain much oxygen, as mentioned in No. 7. 1. of this Section.

Mr.

Mr. Humboldt asserts, that on putting cresses, *lepidium sativum*, into oxygenated muriatic acid gas mixed with water, they produced germs in six hours; while those in common water were thirty-six hours before they produced germs. Jacquin at Vienna put many old seeds, which had been in vain tried if they would vegetate, into such a solution of oxygenated muriatic acid, and found great numbers of them quickly to vegetate. *Journal de Physique*, 1798. See Sect. XIV.

2. 5.

In the experiments of sir Francis Ford many plants, which were sprinkled with water previously impregnated with oxygen gas, are said to have grown more vigorously, and to have displayed more beautiful tints, than those nourished with common water. Other experiments are said to have been made by inverting bottles filled with oxygen gas, and burying their open mouths beneath the soil near the roots of vegetables, which are said to have grown more healthy and beautiful, as the oxygen became absorbed, and was succeeded by air like the common atmosphere. *Philos. Magaz.* 1798, p. 224. Further experiments are required on this subject, since the fluids of vegetables would in general appear to be hyperoxygenated from the oxygen emitted from the perspiration of their leaves in the sunshine, and which is believed to arise from the decomposition of water in their arteries or glands.

9. We now come to the other ingredient, which constitutes a much greater part of the atmosphere than the oxygen, and this is the azote, or nitrogen; which also seems much to contribute to the food or sustenance of vegetables; for though azote, or nitrogen, enters into animal bodies in much greater quantities perhaps than into vegetables, so as to constitute according to some chemical philosophers the principal difference between these two great classes of organized nature; yet it enters also into the vegetable system, and is given out by their putrefaction; and also when lime is applied to moist vegetables it disengages from them both hydrogen and azote forming

volatile alkali, as asserted in the ingenious work of Lord Dundonald on the Connection of Agriculture with Chemistry.

The azote of the atmosphere, when air is confined in the interstices of the soil newly turned over by the plough or spade, contributes to the production of the nitrous acid by its union with the oxygen of the atmosphere, with which it was before only diffused, or with the much greater source of oxygen from the decomposing water of the soil. At the same time another part of the abundant azote combines with the hydrogen of the decomposing water of the soil, and produces ammonia or volatile alkali; which contributes to the growth of vegetables many ways, as already described in No. 2. 6. of this Section.

III. W A T E R.

1. The necessity of much water in the progress of vegetation appears from the great quantity, which exists naturally in all parts of plants; insomuch that many roots, as squill and rhubarb, are known to lose about six parts out of seven of their original weight simply by drying them before the fire; which quantity of moisture nevertheless does not exhale in the common heat of the atmosphere during the life of the root; as is seen in the growth of squills in the shops of the druggists, and of onions on the floors of our store-rooms.

2. A second necessity of much water in the economy of vegetation may be deduced from the great perspiration of plants, which appears from the experiments of Hales and others; who like Sanctorius have estimated the quantity of their perspiration from their daily loss of weight; which however is not an accurate conclusion either in respect to plants or animals, as they both absorb moisture from the atmosphere, as well as perspire it.

This great perspiration of vegetables, like that from the skin and lungs of animals, does not appear to consist of excrementitious matter, because it has in general no putrescent smell or taste; but seems

to

to be secreted first for the purpose of keeping the external surface of the leaves from becoming dry, which would prevent the oxygen of the atmosphere from entering into the vegetable blood through them; since according to the experiments of Dr. Priestley on animal membranes the oxygen will only pass through them, when they are moist. A second use of this great perspiration is to keep the bark supple by its moisture, and thus to prevent its being cracked by the motion of the branches in the wind. And though a great part of this perspirable matter is probably absorbed, as on the skins of animals; yet as it exists on so large a surface of leaves and twigs, much of it must necessarily evaporate on dry and windy days.

3. One of the great discoveries of modern chemistry is the decomposition of water, which is shewn both by analysis and synthesis to consist of eighty-five hundredth parts of oxygen, and fifteen of hydrogen. Hence a third great use of water in the vegetable economy is probably owing to its ready decomposition by their organs of digestion, sanguification, and secretion. This is evinced first by the great quantity of hydrogen, which exists in the composition of many of their inflammable parts. And secondly, from the curious circumstance, which was first discovered by the ingenious Dr. Priestley, that the water, which they perspire, is hyperoxygenated; and in consequence always ready to part with its superabundance of oxygen, when exposed to the sun's light; from whence it may be concluded, that part of the hydrogen, which was previously an ingredient of this water, had been separated from it, and used in the vegetable economy, as is further treated of in Section XIII. 1. 2.

Add to this, that from the decomposition of water, when confined in contact with air beneath the soil, the nitrous acid seems to be produced and ammonia, both which are believed useful to vegetation, as mentioned in No. 2. 6. of this Section.

4. Besides the peculiar uses of a great quantity of water, as above described, the more common uses of it both to vegetable and animal life,

life, along with the matter of heat, are to produce or preserve a due suppleness or lubricity of the solids, and a due degree of fluidity of the liquids, which they contain or circulate. And lastly, for the purpose of dissolving or diffusing in it other solid or fluid substances, and thus rendering them capable of absorption, circulation, and secretion.

5. The due irrigation of the soil is much attended to in drier and warmer countries, as in Italy, Egypt, and some parts of China; where numerous canals, and aqueducts, have been dug through hills, and carried over vallies, for the purpose of watering the soil; and even in this colder and moister climate the practice of flooding land is coming daily into greater repute. For this occasional suffusion of water over land not only supplies simple moisture for the purposes above mentioned in the drier parts of the seasons, but brings along with it calcareous earth and azotic air from the neighbouring springs, or other manures from the rivers. Calcareous earth may be detected in the water of all those springs which pass under or over strata of marle or limestone, by dropping into them a solution of salt of tartar; or of sugar of lead in water, or of soap in spirits of wine; and a portion of azotic gas was discovered in Bath-water by Dr. Priestley, and in Buxton-water by Dr. Pierson. See Section XI. 3. 1. Dr. Home thinks he discovered nitrat of lime in hard water, and found by his experiments that it promoted the growth of plants in a much greater degree than soft water.

6. Another demand for water in agriculture is to give a due penetrability to the soil, which otherwise in most situations becomes so hard as to stop the elongation of the tender roots of plants; but the cohesion of the soil may nevertheless be too much diminished by great and perpetual moisture, so as not to give sufficient firmness to the roots of trees. And besides this too much as well as too little water may be supplied to the generality of vegetables, which grow upon the land; though there are aquatic and amphibious plants as well as

aquatic and amphibious animals, and which differ from each other as fish and seals from quadrupeds.

Where land abounds too much with moisture, the art of making subterraneous or superficial drains described in Sect. XI. 1. must be had recourse to. But where these are not executed, in lands not very moist it is thought advantageous to sow the crops early before the wet season, since corn will bear much more moisture after it has shot from the seed, than the seed will bear; as the seed is less tenacious of life, and in consequence more liable to putrify. The crops should likewise be sown or planted thinner, and be reaped early in the season, as the exclusion of the air by thick foliage, and the greater dampness of the autumn, are liable to generate mildew in moist situations. Perhaps it should be added, that sowing early, and the consequent reaping early, has so many advantages in all seasons on all lands, that it may in general be universally recommended; and that in wet lands it might be very advantageous to cultivate crops by transplantation in the vernal months, having previously sowed the seed in drier or warmer situations. See Sect. XVI. 8. 1.

7. Another injury in this climate occasioned by too great a quantity of water arises from hasty showers; which wash off much of the decomposing animal and vegetable recrements, which are soluble or diffusible in water, and carry them down the rivers into the sea. From the sides of hills this damage is accomplished by small showers, on which account all sloping grounds when applied to agriculture should be ploughed horizontally, as by the ridges and furrows thus produced the smaller showers of rain will not pass so hastily off, as when they are ploughed vertically.

A question here occurs, whether it be advantageous to plough level plains into ridges and furrows? the Chinese are said never to divide their fields into ridges and furrows, but to plant their grain on an even surface. *Embassy to China by sir G. Staunton, Vol. III. p. 197, 8vo. edit.* Some think it an error to suppose, that any increase of crop

crop can be thus obtained, as no more plants can rise perpendicularly from the ground; but in the ripening of grain the surface of air to which the ears are exposed is also to be considered; which corresponds with the surface of the ground, and is increased by its being laid in hill and dale. But there is a serious objection to this mode of ploughing in moist situations without sufficient declivity, as the corn in the furrows appears weak and backward owing to the rain lying on it too long; and also to the best part of shallow soils being frequently taken from them to construct the ridges. See Sect. XVI. 2. 2.

8. Add to this, that the evaporation of moisture from the surface of the earth produces so much cold as to injure those terrestrial plants, which are too long covered with it. On this account those parts of wall-trees, which are sheltered from the descending dews by a coping stone on the wall, are not so liable to be injured by frosty nights on two accounts; both as they are not made colder by the evaporation of the dew, and also have less water to be congealed in their vessels, and by its expansion to burst them.

9. Lastly, the foliage on buds of plants, which constitute one part of their progeny, requires more moisture for its vigorous growth, than their flowers or organs of sexual generation. Hence in warm countries the rice-grounds are flooded only till the season of flowering commences, and are laid dry again for the purpose of maturing the seed; and in our climate continued rains are liable not only to wash off the farina from the bursting anthers, and thus prevent the impregnation of the pistillum, but also to delay the ripening of the fruit or seeds from the want of a due evaporation of their perspirable matter, as well as from the less solar light in cloudy seasons; whence in the north of Scotland the oats are said seldom to ripen till the frost commences with the dry season, which accompanies it.

10. There are methods of procuring or preserving the salutary moisture of the soil besides those of canals and aqueducts, which should

should be here mentioned. These are by using as manures such substances as perpetually attract moisture from the lower part of the soil, or from the atmosphere; as quick-lime, and vegetable and animal recrements in the act of putrefaction.

In hot-houses some have already employed steam as a means both of giving warmth and moisture to the included plants, or to the soil in which they grow; and a great variety of forcing pumps have been constructed for the purpose of moistening the foliage of wall-trees; but there is a hope from the present great progress of chemical research, that a means may sometime be discovered of precipitating the water of the atmosphere, which the ingenious bishop Watson thinks always exists in it in such quantity as, if it was suddenly precipitated, might again deluge the world.

IV. CARBON.

1. When animal and vegetable bodies are burnt without the access of air, that is, when their volatile parts are sublimed; there remains a great quantity of charcoal, a much greater in vegetable bodies than in animal ones; this is termed carbon by the French school, when it is quite pure; and is now known to be one of the most universal materials of nature. And as vegetable bodies contain so much of it in their composition, they may be supposed to absorb it intire, where they grow vigorously; especially as it is a simple material; but they may possibly form it also occasionally from water and air within their own vessels, when they are secluded from access to it externally.

The whole atmosphere contains always a quantity of it in the form of carbonic acid, or fixed air; as is known by the scum, which presently becomes visible on lime-water, when exposed to the air; and which consists of a reunion of the lime with carbonic acid; which may therefore be said to encompass the earth.

The simplicity of carbon, as an elementary substance, was disputed by Dr. Austin, who believed he had decomposed it. But Mr. Henry, by accurately repeating his experiments, has shewn the fallacy or inconclusiveness of them. *Philos. Transact.* 1797.

2. Another great reservoir of carbon exists in limestone in the form of carbonic acid; which when a stronger acid is poured on the calcareous earth becomes a gas, acquiring its necessary addition of heat from that, which is given out in the combination of the stronger acid with the lime. It also acquires its necessary heat, when limestone is burnt, from the consuming fuel, rises in the form of gas, and is dissipated in the air; and probably soon settles on the earth, as it cools, as it is ten times heavier than the common atmosphere.

3. But the great source of carbon exists in the black earth, which has lately been left by the decomposition of vegetable and animal bodies; and is then in a state fit to combine with azote or nitrogen, and with oxygen, when exposed to those two gasses, as they exist in the atmosphere; and is thus adapted either to promote the generation of nitrous acid, or to form carbonic acid, and thus to assist vegetation.

Morasses consist principally of the carbonic recrements of vegetable matters, which are gradually decomposed in great length of time into clay, with argillaceous sand, such as is found over coal-beds, and some calcareous earth, as in marl; and lastly, with some iron, and fossil coal. These by elutriation are separated from each other, and form the strata of coal countries. In other places they remain intermixed, as they were probably produced from the decomposition of vegetables and terrestrial animals; and form what in books of practical agriculture is called a *loamy* soil, consisting of carbonic matter, sand, and clay, with a portion of iron.

It has always been observed, that this black garden mould, or earth produced from the recrements of vegetables, is capable of absorbing a much greater quantity of putrid effluvia than either air or water, and

probably of combining with its ammonia, and producing a kind of hepar carbonis, and thus facilitating vegetation. The practice of burying dead bodies so few feet below the surface is a proof of this; as the putrid exhalations from the carcass are retained, and do not penetrate to the surface. On the same account the air over new ploughed fields has long been esteemed salutary to invalids, or convalescents, as it probably purifies the supernatant atmosphere. But it was not till lately known that carbon, or charcoal, absorbs with such great avidity all putrid exhalations; if it has been recently burnt, and has not been already saturated with them, inasmuch that putrid flesh is said to be much sweetened by being covered a few inches with the powder of charcoal; or even by being buried for a time in black garden mould; as putrid exhalations consist chiefly of ammonia, hydrogen, and carbonic acid, and are the immediate products of the dissolution of animal or vegetable bodies, they are believed much to contribute to vegetation; as whatever materials have constituted an organic body, may again after a certain degree of dissolution form a part of another organic body. The hydrogen and azote produce ammonia, which combining with carbon may form an hepar carbonis, and by thus rendering carbon soluble in water may much contribute to the growth of vegetables.

It has been said, that some morasses have prevented the animal bodies, which have been buried in them, from putrefaction; which may in part have been owing to the great attraction of the carbon of the morass to putrid effluvia, and in part perhaps to the vitriolic acid, which some morasses are said to contain.

4. Here occurs an important question, by what other means is this solid carbon rendered fluid, so as to be capable of entering the fine mouths of vegetable absorbents? The carbon, which exists in the atmosphere, and in limestone, is united with oxygen, and thence becomes soluble or diffusible in water; and may thus be absorbed by the living action of vegetable vessels; or may be again combined by

chemical attraction with the lime, which has been deprived of it by calcination.

When mild calcareous earth, as limestone, chalk, marble, has been deprived of its water and of its carbonic acid by calcination, it becomes lime. Afterwards when it is cold, if water be sprinkled on it, a considerable heat is instantly perceived; which is pressed out by the combination of a part of the water with the lime; as all bodies, when they change from a fluid state to a solid one, give out the heat, which before kept them fluid. At the same time another part of the water, which was added, is raised into steam by the great heat given out as above mentioned; and the expansion of this steam breaks the lime into fine powder, which otherwise retains the form of the lumps of limestone before calcination. But if too great a quantity of cold water be suddenly added, no steam is raised; and the lump of lime retains its form; whence it happens, that some kinds of lime fall into finer powder, and are said to make better mortar, if flaked with boiling water than with cold.

On this account the lime, which is designed to be spread on land, should previously be laid on a heap, and either suffered to become moist by the water of the atmosphere, or flaked by a proper quantity of water; otherwise if it be spread on wet ground, or when so spread is exposed to much rain, the heat generated will be dissipated without breaking the lumps of lime into powder; which will then gradually harden again into limestone, disappoint the expectation of the agricultor, and afflict him with the loss of much labour and expence.

When the powder of flaked lime mixed with sand and water is spread on a wall, that part of the water which is not necessary for its imperfect crystallization, evaporates into the air; and the lime then gradually attracts the carbonic acid, which is diffused in the atmosphere; but as I suppose this carbonic acid is dissolved in the water, which is also diffused in the atmosphere; the lime is perpetually
moistened

moistened by this new acquisition of water from the air ; as that, which before adhered to it, and had parted with its carbonic acid, evaporates. On which account new built walls are months, and even years, in drying, as they continue to attract water along with the carbonic acid from the air, which stands upon them in drops, till the lime regains its original quantity of carbonic acid, and again hardens into stone, or forms a spar by its more perfect or less disturbed crystallization.

5. The earth I suppose acquires carbon, both in a manner similar to the above by its attracting either the carbonic acid, or the water in which it is diffused, from the atmosphere ; and also by the specific gravity of carbonic acid gas being ten times greater than that of common air ; whence there must be constantly a great sediment of it on the surface of the earth ; which in its state of solution in oxygen and water may be readily drank up by the roots of vegetables.

6. Another means by which vegetables acquire carbon in great quantity may be from limestone dissolved in water ; which though a slow process occurs in innumerable springs of water, which pass through the calcareous or marly strata of the earth ; as those of Matlock and Bristol in passing through limestone ; and those about Derby in passing through marl ; and is brought to the roots of vegetables by the showers, which fall on soils, where marl, chalk, limestone, marble, alabaster, fluor, exist ; which includes almost the whole of this island. By this solution of mild calcareous earth in water not only the carbon in the form of carbonic acid not yet made into gas, but the lime also, with which it is united, becomes absorbed into the vegetable system, and thus contributes to the nutriment of plants both as so much calcareous earth, and as so much carbon.

7. Another mode by which vegetables acquire carbon, may be by the union of this simple substance, with which all garden-mould abounds, with pure calcareous earth into a kind of hepar, analogous to the hepar of sulphur made with lime, which abounds in some mineral.

neral waters. And this I suppose to be the great use of lime in agriculture.

For the purpose of ascertaining the probability of this mode of solution of carbon I made the following experiment. About two ounces of lime in powder were mixed with about as much charcoal in powder, put into a crucible, and covered with an inch or two of siliceous sand. The crucible was kept red hot for an hour or longer, and then suffered to cool. On the next day water was poured on the lime and charcoal, which then stood a day or two in an open cup, and acquired a calcareous scum on its surface. And though it had not much taste, except of the causticity of the lime, yet on dropping one drop of marine acid into a tea-spoonful of the clear solution a strong smell like that of *hepar sulphuris* was perceived, or like that of Harrogate water; which evinced, that the carbon was thus rendered soluble in water.

Perhaps the sulphureous smell of Harrogate and Kedleston waters, and other similar springs, may be owing to the union of the alkali of decomposing marine salt with the carbon of the earth, they run through? and this kind of water might thus possibly be used as a profitable manure?

8. Another mode by which vegetable roots acquire carbon, I suspect to be by their disuniting carbonic acid from limestone in its fluid not its gaseous state; which the limestone again attracts from the atmosphere and consolidates, or from other matters included in the soil. First, because lime is believed by some agricultors, who much employ it, to do more service in the second year than in the first; that is in its mild state, when it abounds with carbonic acid, than in its caustic state, when it is deprived of it.

Secondly, that the use of burning lime seems hence to be simply to reduce it to an impalpable powder, almost approaching to fluidity; which must facilitate the application of the innumerable extremities of vegetable fibres to this uncalculable increase of its surface; which
may

may thence acquire by their absorbent power the carbonic acid from these minute particles of lime, as fast as they can recover it by chemical attraction from the air, or water, or from other inanimate substances in their vicinity.

Thirdly, the hyper-oxygenation of the perspirable matter of plants, which thence gives up oxygen gas in the sunshine, would induce us to believe, that a great part of the carbon, which furnishes so principal a part of vegetable nutriment, was received by their roots in the form of carbonic acid; and that it becomes in part decomposed in their circulation, giving up its oxygen; which thus abounds in the secreted fluids of vegetables from this source, as well as from decomposed water.

9. Another way by which carbon is received into the vegetable system is by its existence in sugar and in mucilage; both which are taken up undecomposed, as appears by their presence in the vernal sap-juice, which is obtained from the maple and the birch; which like the chyle of animals, is absorbed in its undecomposed state.

V. PHOSPHORUS.

1. Another material which exists, I believe, universally in vegetables, and has not yet been sufficiently attended to, is phosphorus. This like the carbon, nitrogen, hydrogen, and sulphur, is probably a simple substance; as our present chemistry has not yet certainly analysed any of them; and therefore I suppose it is taken up intire by the absorbent vessels of vegetables, when it can be met with in a state of solution; though it may also be occasionally formed and secreted by them; and may hence be registered among the articles of their food or sustenance.

When wood is decomposed by putrefaction in a certain degree of warmth and moisture, it is often seen to emit much light in dark evenings, when recently broken and exposed to the oxygen of the atmosphere,

atmosphere, so as to alarm benighted passengers; which is undoubtedly owing to the phosphorus, which it contains, and which is at this time converted into phosphoric acid. Such a light frequently is seen on putrescent veal, when kept in a certain degree of warmth and moisture; and on the sea-weed placed on the oysters packed in barrels, and sent into the country; and in the streets of Edinburgh, where the heads of the fish called whittings or haddies are frequently thrown out by the people, I have on a dark night easily seen the hour by holding one of them to my watch.

2. The existence of phosphorus in vegetables was detected by Margraaf; who found, that many vegetable matters, particularly farinaceous grains, contain enough of the phosphoric acid to produce phosphorus, when they are exposed to great heat in close vessels. Macquer's Chemical Dictionary translated by Mr. Keir, Vol. II. p. 535, Art. Phosphorus. Phosphorus has been detected in gum arabic, sugar, honey, flour, and in every kind of vegetable or animal substance by the process of making the phosphorus of Homberg. And the existence of phosphorus in greater quantity in all the parts and recrements of animals, as in their flesh, dung, urine, and bone-ashes, and most copiously in the two latter, is evinced in the fabrication of Kunkel's phosphorus. Whence its universal existence is discovered in these two great kingdoms of nature. See the above Dict. Art. Pyrophorus.

The most easy process for producing Homberg's phosphorus consists in mixing three parts of alum with one of sugar, which are to be exposed to a great heat in a covered crucible, till a bluish flame has appeared for some time. It must then be suffered to cool a little, and be put into a dry hot bottle, and closely stopped from the air. A drachm of this powder will afterwards, when poured from the bottle into the open air on paper, quickly kindle, become red like burning coals, and burn the paper, which it lies upon.

Hence we may conclude, that vegetable bodies, as well as animal
ones,

ones, contain acid of phosphorus; and that in this experiment the acid of the alum takes the fixed alkaline salt from the vegetable ashes, and the calcareous earth, if such there be, and that the carbon unites with the oxygen of the phosphoric acid; and the vegetable phosphorus is left mingled with the earth of alum; exactly in the same manner as the animal phosphorus is obtained from the ashes of bones, or the salt of urine, by calcining them in close vessels with charcoal.

3. An important question now occurs; if this simple material of phosphorus be not generally made in the vessels of vegetables, whence do they acquire it? They may probably obtain it in considerable quantity from the recrements of decaying vegetable and animal bodies; as it appears in rotten wood, and in putrefying fish, and exists in such large quantities in bone-ashes, and in the salt of urine. But I suppose there is another great source of phosphorus, I mean in calcareous earth, which also has been of animal origin in the early ages of the world.

If an oyster-shell be calcined for about half an hour in a common fire, and is then kept from the air in a cold place; when it is afterwards exposed for a while to the sunshine, and brought into a dark room, it will appear luminous like the calcined Bolognian stone; which is owing to the phosphoric acid thus deprived of its oxygen by the carbon of the fire-coals, and intermingled with the pure calcareous earth or lime of the shell; and which again combining with the oxygen of the air, both light and heat are emitted in the reproduction of phosphoric acid. See Wilson on Phosphori, Doddsley, London, 1795.

The Bolognian stone is a selenite or gypsum, which consists of vitriolic acid and calcareous earth, and I suppose of acid of phosphorus; since on mixing the powder of this stone with gum arabic, and calcining it some time, a kind of phosphorus is produced similar to the above, owing I suppose to the carbon of the fire coals, or of the gum arabic, carrying off the oxygen from the phosphoric acid; which pre-

viously existed both in the calcareous earth of the selenite, and in the ashes of the gum arabic.

Mr. Canton, in the *Philos. Transact.* Vol. LVIII. p. 337, published his making a pyrophorus by calcining oyster-shells, and then mixing them reduced to powder with sulphur, and recalcining them in close vessels. This powder after being exposed to light, or heated by other means, became luminous in the dark for many minutes. By this process the acid of phosphorus existing in the animal shell had been decomposed by the red hot sulphur having robbed it of its oxygen; and thus the phosphorus remained united with the calcareous earth.

M. Du Fay, in a memoir published in the year 1730, asserts from experiments, that all calcareous stones, whether they contain vitriolic acid or not, are capable of becoming luminous by calcination; with this difference only, that the pure calcareous stones require a stronger or repeated calcination; whereas those, which contain an acid, as selenites, or gypsum, become phosphoric by slighter calcination. M. Margraaf also asserts, that all kinds of calcareous stones may by calcination be rendered phosphoric; but thinks, that the pure ones should be previously saturated with an acid. *Keir's Dict. Art. Phosphorus.* And lastly, some kinds of fluor, which is known to consist of calcareous earth and the fluor-acid, emit phosphoric light on being heated slowly, but lose it, when much ignited. (*Kirwan's Mineralogy.*) This material might probably as well as gypsum become useful in agriculture.

4. These experiments, which shew that all common calcareous stones, which contain only carbonic acid, were rendered phosphoric by calcination; but that those which did contain a fixed acid, as gypsum, and fluor, were rendered phosphoric with less difficulty, acquaint us first with perhaps one very important use of lime in agriculture. Secondly, with that also of gypsum, or alabaster, which has lately been used in America and in Germany without previous calcination; but

but which might probably be more successful after calcination. And thirdly, with the probable use of fluor spar in its recent or calcined state. As there is reason to believe, that the vegetable system may absorb phosphorus from any of these materials; which phosphorus may originally have been of animal origin, as well as that which exists in feces and urine. And lastly, the use of recent shells or bones ground into powder, or of bone-ashes, spread on land may be deduced; as they consist almost entirely of phosphorus and calcareous earth.

5. In the conversion of shells into limestone there seems to have been either simply an additional quantity of carbonic acid attracted from the air or from water during the procession of ages, and added to the calcareous earth, or also a diminution of the phosphoric acid. But an union of phosphoric acid only with lime has lately been found to compose whole mountains in Spain, which is mentioned by Fourcroy, and is now termed phosphate of lime, resembling bone-ashes. And M. Brumaire lately received from Spain a yellowish translucent stone, called chrysolite by the jewellers, which he found to contain nearly equal parts of phosphoric acid and calcareous earth, and to be a spar or crystallization of the phosphate of lime. And as the limestone at Breedon has lately been discovered to contain equal parts of magnesia and lime, we may hope by greater attention to discover a mountain of phosphate of lime in our own country. See Nicholson's Journal 1798, p. 414.

From hence it would appear, that the immense quantities of limestone in the world, which was originally formed from the shells of submarine animals, has during the long lapse of time lost more or less of its original phosphoric acid, and acquired more or less carbonic acid. The carbon dissolved in the atmosphere or in the ocean having thus slowly decomposed the phosphoric acid in the elaboratory of nature without great heat, as it does in our crucibles in a short time by the assistance of great heat.

It is probable that much phosphorus may be consumed in our inartificial mode of burning lime, which might be preserved by calcining limestone in close vessels, and thus detaching the carbonic acid without admitting the aerial oxygen to the phosphorus; but the advantage to agriculture of such a process can only be determined by experiment.

There are many instances given by Mr. Anderson, and by Lord Kaimes, of soils which are said to have been for ages uncommonly fertile without addition of manures or culture. These are plains near the shore in the county of Caithness, and in the Hebrides, and are said to consist almost entirely of shells broken into very small particles, without almost any mixture of other soil. See *Encyclop. Britan. Art. Agricult.* Now the soil of an extensive country called Lincoln Heath I observed some years ago to consist in a great degree of powdered limestone, which like the Ketton limestone appeared in small rounded particles, which I suppose had in remote times been dissolved in water, and again precipitated; which shews a probable difference between this lime and recent shells in respect to their antiquity, and consequently that the former must contain much of the original phosphoric acid, and the latter only carbonic acid. And as Lincoln Heath was then esteemed a very unproductive soil, there is reason to infer that the phosphoric acid in recent shells is of greatly more service to agriculture than the carbonic acid of alluvial limestone, or than calcined lime alone.

Hence it is probable, that a greater quantity of phosphoric acid may exist in some marles than in others, as well as in some limestones; thus the appearance of recent shells exists in the lime near Loughborough in Leicestershire, in the road to Nottingham, and in some marles called shell-marle; which must therefore probably contain much more phosphoric acid, so as almost to resemble the bones of animals; and may thus be more friendly to vegetation. A piece of land is mentioned by Mr. Anderson, that, after a thick coat of marle

laid on it, bore crops for thirty years without additional improvement, and I think it was called shell-marle. See *Encyclop. Britan. Agricult.*

6. A medical philosopher, M. Bonhomme, has endeavoured to shew, that the hardness of animal bones depends on the quantity of phosphoric acid united to calcareous earth, which they contain; and that the rickets, a disease in which the bones become too soft, is solely owing to the want of it, or to the existence of the vegetable acid instead of it. *Annales de Chemie*, Vol. XVII. May we not conclude, that the presence of phosphoric acid in the vegetable system must be of importance; because it so universally exists in them, and may probably give firmness to liqueous as well as to osseous fibres? To which may be added, that M. Fourcroy believes, that the ashes of burnt vegetables, which have been supposed to consist of earth or clay, when the fixed alkali is washed from them, are principally calcareous phosphorus, like those of animal bones. The same is asserted by Lord Dundonald in his *Connection of Agriculture and Chemistry*, p 25, who calls the insoluble part of vegetable ashes a phosphat of lime. This subject is worthy further investigation.

VI. L I M E.

Many of the principal uses of calcareous earth in promoting the growth of vegetables have been already mentioned in this section, which we shall recapitulate with additions.

1. One great use of calcareous earth I suspect to consist in its uniting with the carbon of the soil in its pure or caustic state, or with that of vegetable or animal recrements during some part of the process of putrefaction; and thus rendering it soluble in water by forming an *hepar carbonis*, somewhat like an *hepar sulphuris* produced by lime and sulphur, as mentioned in No. 4. 7. of this Sect.; by which process

cess I suppose the carbon is rendered capable of being absorbed by the lacteal vessels of vegetable roots.

The black liquor, which flows from dunghills, is probably a fluid of this kind ; but I mean to speak hypothetically, as I have not verified it by experiment ; and the carbon may be simply supported in the water by mucilage, like the coffee drank at our tea-tables ; or may be converted into an hepar carbonis by its union with the fixed alkali of decaying vegetable matter, or by the volatile alkali, which accompanies some stages of putrefaction. See No. 10. 3. of this Section.

2. A second mode of its serving the purposes of vegetation I believe to be by its union with carbonic acid, and rendering it thus soluble in water in its fluid state instead of its being expanded into a gas ; and that thus a great quantity of carbon may be drank up by vegetable absorbent vessels.

In the practice newly introduced of watering lands by deriving streams over them for many weeks together, I am informed that water from springs is generally more effectual in promoting vegetation than that from rivers ; which though it may in part be owing to the azotic gas, or nitrogen, contained in some springs, as those of Buxton and of Bath, according to the analysis of Dr. Priestley, and of Dr. Pearson ; yet I suppose it to be principally owing to the calcareous earth, which abounds in all springs, which pass over marly soils, or through calcareous strata ; and which does not exist in rivers, as the salts washed into rivers from the soil all seem to decompose each other, except the marine salt, and some magnesian salt, which are carried down into the ocean. The calcareous earth likewise, which is washed into rivers, enters into new combinations, as into gypsum, or perhaps into siliceous sand, and subsides. These solutions of calcareous earth in those waters, which are termed hard waters, and which incrust the sides of our tea-kettles, may possibly also contribute

tribute to the nutriment of animals, as mentioned in *Zoonomia*, Part III. Article I. 2. 4. 2.

3. A third mode, by which lime promotes vegetation, I suppose may be ascribed to its containing phosphorus; which by its union with it may be converted into an hepar, and thus rendered soluble in water, without its becoming an acid by the addition of oxygen. Phosphorus is probably as necessary an ingredient in vegetable as in animal bodies; which appears by the phosphoric light visible on rotten wood during some stages of putrefaction; in which I suppose the phosphorus is set at liberty from the calcareous earth, or from the fixed alkali, or from the carbon of the decomposing wood, and acquires oxygen from the atmosphere; and both warmth and light are emitted during their union. But phosphorus may perhaps more frequently exist in the form of phosphoric acid in vegetables, and may thus be readily united with their calcareous earth, as mentioned in No. 5. 6. of this Section, and may be separated from its acid by the carbon of the vegetable during calcination, and also during putrefaction, which may be considered as a slow combustion.

The existence of a solution of phosphoric acid and calcareous earth in the vessels of animals is proved by the annual renovation of the shells of crab-fish, and by the fabrication of the egg-shells in female birds; and is occasionally secreted, where it cements the wounds made on snail-shells; or where it joins the present year's growth of a snail-shell to the part, where a membranous cover had been attached for the protection of the animal during its state of hibernation. And lastly, it is evident from the growth of the bones of quadrupeds, and from the deposition of callus to join them where they have been broken.

4. Lime in its pure state is soluble in about 600 times its weight of water; and by a greater quantity of carbonic acid than is necessary for its crystallization, it is soluble in water in much greater quantities, as appears by the calcareous deposition of the water at Matlock;

lock; and may I suppose supply a nutritious substance by uniting with mucilage or oil, either in the earth at the roots of vegetables, or on the surface of the soil, which may be gradually washed down to them.

If a solution of soap be poured into lime-water, the oil of the soap combines with the calcareous earth, and the caustic alkali is set at liberty, according to the experiments of Mr. Bertholet; (see Nicholson's Journal, Vol. I. p. 170,) who concludes, that oil has a stronger affinity to calcareous earth than it has to fixed alkali. At the same time it appeared, that a solution of the mild or effervescent fixed alkali poured on this calcareous soap would decompose it by twofold elective attraction; as the carbonic acid of the mild fixed alkali unites with the calcareous earth of the calcareous soap, and the oil unites with the pure or caustic alkali.

Many arguments may be adduced to shew, that calcareous earth either alone, or in some of the states of combination above mentioned, may contribute to the nourishment both of animals and vegetables. First, because calcareous earth constitutes a considerable part of them, and must therefore either be received from without, or formed by them, or both. Secondly, because from the analogy of all organic life, whatever has composed a part of a vegetable or animal, may again after its chemical solution become a part of another vegetable or animal; such is the general transmigration of matter!

5. There are other uses of lime in agriculture, which may not be ascribed to it as a nutritive food for vegetables, but from its producing some chemical or mechanical effects upon the soil, or upon other manures, with which it is mixed; as first, from its destroying in a short time the cohesion of dead vegetable fibres, and thus reducing them to earth; which otherwise is effected by a slow process, either by the consumption of insects, or by a gradual putrefaction. This is said to be performed both by mild and by caustic calcareous earth, as in the experiments both of Pringle and Macbride. It is said that
unburnt

unburnt calcareous earth forwards the putrefaction of a mixture of animal and vegetable matter. But that pure lime, though it seemed to prevent putrefaction, destroyed or dissolved the texture of the flesh. Thus I am informed, that a mixture of lime with oak-bark, after the tanner has extracted from it whatever is soluble in water, will in two or three months reduce it to a fine black earth; which if only laid in heaps, would require as many years to effect by its own spontaneous fermentation or putrefaction. This effect of lime must be particularly advantageous to newly enclosed commons when first broken up.

Mr. Davis, in the papers of the Society of Arts, Vol. XVI. p. 122, asserts, that on a common, which had been previously covered with heath, but was otherwise very barren, the effect of lime was very advantageous for about ten years, during which time the vegetable roots might be supposed to have been dissolved and expended; but that a second liming he observed produced no good effect. It is probable the good effect might not be so great, but I should doubt the circumstance of its producing no good effect at all.

Mr. Browne of Derby has also an ingenious paper in the transactions of the Society of Arts, in which he asserts, that recent vegetables, as clover, laid on heaps and stratified with fresh lime, are quickly decomposed, even in a few days. The heat occasioned by the moisture of the vegetables uniting with the lime I suppose quickens the fermentation of the vegetable juices, and produces charcoal in consequence of combustion, similar to that frequently produced in new haystacks, which if air be admitted burst into flame.

Secondly, lime for many months continues to attract moisture from the air or earth; which it deprives I suppose of carbonic acid, and then suffers it to exhale again, as is seen on the plastered walls of new houses. On this account it must be advantageous when mixed with dry or sandy soils, as it attracts moisture from the air above, or

the earth beneath ; and this moisture is then absorbed by the lymphatics of the roots of vegetables.

Thirdly, by mixing lime with clays it is believed to make them less cohesive ; and thus to admit of their being more easily penetrated by vegetable fibres.

Fourthly, a mixture of lime with clay destroys its superabundance of acid, if such exists ; and by uniting with it converts it into gypsum, or alabaster.

Fifthly, when lime is mixed with a compost of soil and manure, which is in the state of generating nitrous acid, it arrests the acid as it forms, and produces a calcareous nitre, and thus prevents both its exhalation and its easy elutriation.

And lastly, fresh lime destroys worms, snails, and other insects, with which it happens to come in contact, and with which almost every soil abounds.

6. The various properties of lime above described account for the great uses of it on almost all lands ; except perhaps some of those which already abound with calcareous earth.

On riding from Beckingham to Sleaford, and from thence to Lincoln, I was informed by three or four farmers, that lime had been tried, but was believed to be of no service in that country. Nor was I surprised at this observation, as I had seen fragments of alluvial limestone thrown out of every ditch on the road, which was of a loose texture, consisting of calcareous sand, like the Ketton limestone, rounded by friction, before it was consolidated into a mass, the upper surface of which was broken into fragments, when it was raised from the sea by subterraneous fires, or by its cooling from a hot state or its drying from a moist one.

Thus, as I had ridden over one single alluvial limestone above ten miles broad and above twenty long, the broken surface of which appeared in the bottom of almost every ditch, I concluded, that the soil must be calcareous earth mixed only with some animal and vegetable

getable recrements, and that an addition of pure lime could probably not be of much advantage to the vegetables it supported. And the same I suppose must occur in those situations, where the surface of the soil consists almost totally of chalk, which is another kind of alluvial limestone; that is, which has been dissolved in water in the early ages of the world, and again deposited.

Yet even in some soils, which abound in calcareous earth, lime is esteemed to be of service; which may be owing both to its caustic quality, and to its being so finely pulverized. For a part of the water, which combines with it after calcination, gives out so much heat as to convert another part of it into steam; which breaks the calcined lime-lumps into a most subtile and impalpable powder, approaching even to fluidity, as mentioned in No. 4. 4. of this Section.

In the parish of Hartington in Derbyshire there is a stratum of hard limestone, or marble, as I am informed, immediately beneath a shallow soil, and which in many places peeps through it; yet on some of this land an ingenious active agricultor has laid lime on the grass in great quantity with prodigious advantage; and that he continues annually to improve by this means a considerable extent of land.

The difference between the hard limestone of this part of Derbyshire, and the soft sand-formed limestone about Lincoln Heath and Sleaford, may render the incumbent soil to be more or less mixed with calcareous earth; or they may abound more or less with phosphoric acid, as mentioned in No. 5. 5. of this Section. But it may have happened, that some prejudices of the farmers, who gave me the information, might have led them to condemn the use of lime about Sleaford and Lincoln; and I should again recommend it to their serious attention.

Another improper situation for the use of lime is said to be on those lands, which are too wet, and which therefore should be previously drained; otherwise the lime is said to coalesce into a kind of mortar,

and become so hard, that the tender plumula of growing seeds, or the fine extremities of their roots, can not easily penetrate it. This may occur more certainly in that kind of lime, which contains manganese, and is therefore capable of setting under water, as, I suppose, the barrow lime of Leicestershire, and agnes lime near Ashbourn in Derbyshire.

7. The great and general advantage of lime in all soils and all situations, except some of those which are already replete with calcareous earth, or are too moist, can only be understood from the idea already mentioned of its supplying actual nutrition to vegetables; and this seems more probable, as it contributes so much to the melioration of the crops, as well as to their increase in quantity. Wheat from land well lined is believed by farmers, millers, and bakers, to be, as they suppose, thinner skinned; that is, it turns out more and better flour; which I suppose is owing to its containing more starch and less mucilage.

Hence we perceive another very important use of lime in cultivation of land may be owing to its forwarding the conversion of mucilage into starch, that is, to its forwarding the ripening of the seed; which is a matter of great consequence in this climate of short and cold summers. See Sect. VI. 3. and XVI. 3.

In respect to grass-ground I am informed, that if a spadeful of lime be thrown on a tuffock, which horses or cattle have refused to eat for years, they will for many succeeding seasons eat it quite close to the ground; which is owing, I suspect, to the grass containing more sugar in its joints; or to the less acidity of all its juices.

8. There are not only some other bodies, which possess a calcareous base, besides the common limestone, as gypsum, fluor, bone-ashes, and perhaps vegetable ashes; but there are others which are occasionally united with carbonic acid, and may be detached from it by calcination, as the aerated barytes and magnesia. The last in its calcined state may possibly be as useful in agriculture as the lime of calcareous

calcareous earth, with which I believe it is frequently mixed. For Mr. Tennant assured me a few days ago, that he had analysed the limestone of Breedon in Leicestershire, and found it to contain nearly as much magnesia as calcareous earth, besides some manganese; which is nevertheless a lime much esteemed in this country both for architecture and agriculture. As magnesia exists in sea-water, and in salt springs, it may render these waters useful as a manure as well as the marine salt, which they contain. As steatites or soap-stone consists principally of magnesia, perhaps this limestone of Breedon may be worth the attention of the porcelain manufactory.

This magnesian lime of Breedon is further worthy attention in the cultivation of land, and particularly where a soil abounds with vitriol of iron, or where it abounds with gypsum, as about Chelaston on the banks of the Derwent, and from Nottingham to Newark on the banks of the Trent, as the magnesian earth would unite with the vitriolic acid, and leave an ochre of iron in one case, and lime in the other; at the same time a soluble salt, called Epsom salt, would be formed, which, according to the experiments of Dr. Home, promotes rapid vegetation. To sow a few pecks of gypsum reduced to powder on grass land, as is done in America; and then to sow upon this twice or thrice as much Breedon lime, might be an experiment which might be advantageous in the part of Derbyshire next to Leicestershire, where both of them are to be obtained at no great expence.

VII. CLAY, METALLIC OXYDES, NITRE, SEA-SALT.

1. The too great adhesion of the particles of argillaceous earth or clay renders it in its pure state unfit for vegetation; as the tender fibrils of roots can with difficulty penetrate it, whence it becomes much improved for the purposes of agriculture, when it is mixed with calcareous earth and with siliceous sand, as in marle.

It is commonly believed that lumps of clay become meliorated by
being.

being exposed to frost in its moist state, which by expanding the water, which it contains, by converting it into ice is supposed to leave the particles of the clay further from each other. This however seems in general to be a mistaken idea, since if the act of freezing be not very suddenly performed, a contrary effect seems to occur, as noticed by Mr. Kirwan; who observes, “that clay in its usual state of dryness can absorb two and a half times its weight of water without suffering any to drop out, and retains it in the open air more pertinaciously than other earths; but that in a freezing cold clay contracts more than other earths squeezing out its water, and thus parting with more of it than other earths.” *Mineralogy*, Vol. I. p. 9.

This curious circumstance, that water, as it crystallizes, detrudes the clay, which is diffused in it, corresponds with other facts of congelation. Thus when wine, or vinegar, or common salt and water, or a solution of blue vitriol in water, are exposed to frosty air; the alcohol, the acetous acid, the marine salt, and the calx of copper, are all of them detruded from the aqueous crystals, and retreat to the central part of the fluid, or to that last frozen, or into numerous cells surrounded with partitions of ice, as I have frequently observed; whence it appears, that wet clay is in general rendered more solid and tenacious by being frozen, as well as when it is dried, and its moisture exhaled by too warm a sun; and by both those circumstances becomes less adapted to the purposes of agriculture.

2. In most clays a kind of effervescence occurs, after they are turned over, and thrown on heaps, and thus acquire air into their intestines, which renders them much fitter for the purposes of vitrification; and thus forwards the processes of the brick-kiln and pottery. This greater facility to vitrify is probably effected by the union of oxygen with the iron, which most clays contain; as oxydes of lead and manganese are used in the more perfect vitrifications.

The calciform ores, or oxydes, of iron, manganese, and zinc, are frequently found near the surface of the earth, where they have been

united with oxygen by the passing currents of the atmosphere; and have been supposed to have originated from the decomposition of vegetables and animal bodies, as mentioned in Botanic Garden, Vol. I. additional note 18. Iron has been detected in all vegetable and animal matters, manganese in some of them; and, if we possessed a test for discovering such minute particles of zinc, as the magnet discovers of iron, it is probable, that zinc also would be detected in the vegetables, which grow over its beds.

As some philosophers have lately contended for the great utility of oxygen in vegetation, as Humboldt and Von Uslar; who affirm from their experiments, that hyper-oxygenated muriatic acid used in small quantities promotes both the growth and irritability of plants; there is reason to suspect, that the calciform ores of iron, manganese, and zinc, as well as minium, and other calces or oxydes of metals made by fire, and even burnt clays, when strewed on the ground, may contribute to vegetation by their parting with their abundant oxygen in a fluid, not in a gaseous form; which uniting with carbon, or phosphorus, or nitrogen, without emitting perceptible heat or light, might supply nutritious fluids to the roots of vegetables; further experiments are wanted on this subject. But I am well informed, that a red ocher of iron, called raddle, has been used on some lands with advantage in the north of Staffordshire; and should recommend a trial of manganese in those countries, where it abounds, as near Kingsbury, and near Atherstone in Warwickshire; and a trial of lapis calaminaris, where it abounds, as near Matlock in Derbyshire; and even of the calciform ore of lead, which is found in Anglesey, and on the top of some other lead mines.

M. Humboldt asserts, that he mixed many seeds into a kind of paste with the black oxyde of manganese, and poured over it the muriatic acid diluted with water, in the proportion of about six of water to one of acid; and that much oxygen was thus disengaged, and occasioned

ed quick vegetation. *Journal de Physique*, 1798. See No. 2. 8. of this Section.

3. When clays are turned up with the spade, as is usual in preparing them for the brick kiln, a kind of effervescence occurs, as mentioned above; which is probably owing to the escape of the azote of the air imprisoned in the interstices, as the oxygen unites with some metallic particles in the clay; or to steam raised from the water in the clay by the heat set at liberty from the combination of the oxygen and the iron. This union of oxygen with iron is curiously almost visible in many granates or porphyries; which I have seen thinly scattered in large nodules near Cannock in Staffordshire, in the road from Lichfield to Shrewsbury; and on breaking them have observed no appearance of iron on the newly divided surfaces; but which in a few days acquired an ochery appearance on them, which penetrated nearly half an inch. This can not but be ascribed to the oxygen of the atmosphere having united with the iron in these stones, which by their smell, when breathed upon, contain indurated clay, and having converted into an oxyde either the clay itself, or some metallic particles included in it.

There is nevertheless an exhalation from clay, and perhaps from most soils, when they have been previously dried, and then sprinkled with water, as after a shower in summer, which has been supposed to be salubrious to invalids and convalescents. This remarkably occurs, when dry clay is breathed upon even in its most indurated state, as in granites and porphyries, by which criterion these stones are immediately distinguished from the siliceous and calcareous ones. This I imagine is produced by the heat set at liberty by the combination of dry clay and water, like that produced in so much greater degree by the combination of lime and water; and that this heat raises a part of the acquired moisture into steam, in which are dissolved the odorous particles; both which probably cause the quick vegetation on clayey soils after the showers in summer.

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When marl, which consists of clay, calcareous earth, and sand, which are frequently coloured red by iron, or blue probably by manganese, is exposed in small lumps to the atmosphere; it is liable to crumble into powder, which I suppose to arise from a similar circumstance; that the oxygen of the atmosphere uniting with the clay, or the metallic particles it possesses, lets at liberty the same gas, or steam, which is seen to rise from clay, when thrown on heaps for the brick kiln or pottery; which breaks the lumps into powder, as the lumps of lime are broken into powder by the steam, which is generated when water is thrown on them, by the heat set at liberty by the combination of the lime and water.

This union of oxygen with the clay, or with the metallic particles mingled with it, I suppose to be much facilitated by exposing it to a red heat, as in burning bricks; while a greater heat may unite so much oxygen with it as to turn it into glass. Exactly such a process occurs in the production of minium; a certain quantity of heat with the contact of air combines so much oxygen with the melted lead, as to form an oxyde; a greater quantity of heat converts it into glass.

4. When clay is united with so much oxygen by fire as to form a soft or imperfect brick, it possesses the power of promoting the generation of the nitrous acid in certain situations; which is frequently seen like an efflorescence on mouldering walls, having become by the addition of lime a calcareous nitre. The use of these soft bricks in the production of nitre is well known in Paris, where the rubbish of old houses is regularly purchased for that purpose; which before the revolution was a royal manufacture.

As these soft efflorescent bricks from old houses are known powerfully to promote vegetation, when pulverized and mixed with the soil; at the same time that they are capable of producing the nitrous acid; I imagine, that the use of paring and burning the turf of some newly enclosed commons depends on this circumstance. That is,

that the heat emitted from the burning vegetable fibres unites oxygen with the clay; which latter forms more than half of the slices of turf, as they are dug from the ground. In other respects the paring and burning of grass grounds would certainly be a wasteful procedure; as much carbon is converted into carbonic acid, and dispersed along with the uninflamed smoke or foot, and nothing left but the vegetable ashes. From these considerations it would probably be worthy experiment in farms, where coal and clay abound, to burn the latter to a certain degree; which might supply an exhaustless source of profitable manure.

5. I have suspected also, that this calcined clay, as it exists in soft bricks, has a power of decomposing marine salt, as I once observed in a cellar, where beef had been long salted on one side of a nine-inch wall, the wooden salting-tub for which was attached to it; that a great efflorescence appeared on the other side of the wall, which I believed to be fossil alkali or natron. If this idea be just, the soft bricks from old buildings, or clays so far purposely burnt, may in this manner be serviceable to vegetation, by separating the fossil alkali from the sea-salt, which is washed from decomposing animal and vegetable substances; which by converting carbon into an hepatic carbonis, as lime is supposed to do in No. 6. 1. of this Section, might render it soluble in water, and capable of being absorbed by the lymphatic vessels of the roots of plants.

If clay calcined to a certain degree, and thus united with oxygen, possesses the power of decomposing marine salt, there is reason to believe, when it is more slowly united with oxygen by its exposure to the atmosphere by the spade or plough, that it may possess the same property; and that this may have given rise to the very contradictory reports concerning the use of sea-salt in agriculture; as it may probably be of great advantage to clayey soils, but perhaps not so to other soils. See Sect. XIV. 2. 8.

6. Another saline body, which readily unites with argillaceous earth

earth in the fire, is salt of urine, commonly called microcosmic salt, which acts as a flux dissolving clay with considerable effervescence. Kirwan's Mineralogy, Vol. I. p. 9. This microcosmic salt consists of phosphoric acid united with an ammonical, or with a calcareous base; and must in the latter case resemble the phosphat of lime, of which there are whole mountains discovered in Spain, as mentioned in No. 5. 5. of this Section; and of which many may probably be discovered in our own country. Now as the same combinations of matter, which are quickly formed by the heat of the chemist's furnaces, are often performed, though more slowly, in the elaboratory of nature; it is probable, that if this calcareous phosphorus could be procured in this country, reduced to powder, and spread on our clay lands, that it might more than any other calcareous matter render them friendly to vegetation, like the ashes of burnt bones; which experiment alone can determine.

7. As clay is less adapted to the growth of the roots of plants by the too great cohesion of its particles, this may be in some degree corrected by frequently exposing it to air imprisoned in its interstices, as by turning it over by the plough or spade. Another method is by planting on it such vegetables first as are known to grow well in clay, as beans, and as their roots are afterwards left in the clay, they not only thus form tubes in it, so as to render the mass less cohesive; but add to it so much carbon, and thus rather enrich than impoverish it. Add to this that the lower leaves of the dense foliage of these vigorous vegetables are believed to give out much carbonic acid by their respiration in the shade similar to the respiration of animals; which perpetually sinking down upon the surface of the soil is believed to supply it with carbon; and thus also to render it more nutritive to other vegetables, which may afterwards grow upon it.

Lord Kaimes, who allows that clay, if it be moistened after it has been pulverized, becomes on drying as indurated and cohesive as

before, asserts, that this does not happen, if it be moistened with the fluid, which escapes from dunghills; which may be owing both to the carbon, and to the fixed vegetable alkali, which that fluid contains. And also adds, that lime will prevent the cohesion or induration of clay, and therefore greatly improves argillaceous soils for all the purposes of agriculture.

8. When clay abounds with vitriolic acid so as to be converted into alum, it becomes very unfriendly to vegetation. In this state it is believed much to counteract the process of putrefaction in animal bodies, as is said to have happened in some burying grounds. This it may effect by uniting with the ammonia generated by putrefaction the moment it is formed, or by preventing its production; as when the salt of Neville Holt water in Leicestershire, which I suppose is alum, is mixed with very putrid blood, as I once witnessed, the putrid scent was instantly destroyed, as I suppose the argillaceous earth was precipitated.

Where this acid or aluminous clay abounds, it is believed to check the vegetation of trees as well as of herbaceous plants by eroding the fine extremities of their roots, as mentioned in Sect. II. 9. which is perhaps best to be remedied in gardens by wood-ashes or soap-suds, and in larger fields by mixing lime, or chalk in powder, or the sweepings from roads, which are repaired by limestone, with these aluminous clays. Or lastly, where it can be procured, by mixing with them such lime as that of Breedon in Leicestershire, which consists of equal parts of magnesia and calcareous earth, which would thus fabricate what has been termed Epsom salt, which is said to be friendly to vegetation.

VIII. MANURES BY SPONTANEOUS DECOMPOSITION.

We shall now consider more generally the decomposition of organized matter, which vegetable and animal bodies spontaneously undergo,

dergo, when they cease to live. The processes of this decomposition have commonly been divided into the vinous, acetous, and putrefactive fermentations; which have been supposed uniformly to succeed each other. But it is more probable, that different kinds or parts of dead organized matter may be subject to many different kinds of chemical changes, and that these may vary with the degrees of heat, and the quantity of water, and of air, with which they are surrounded.

1. In the stomachs of animals a saccharine process precedes the vinous fermentation; which last only occurs, when the animal power of digestion or absorption is for a time suspended. A similar process occurs in the germination of vegetable roots, whereby meal is converted into sugar, as in the malt-house; and in the gradual ripening of apples and pears, after they are plucked from the tree; but all these may be said to be still alive; and this change of meal or of mucilage into sugar may thus be esteemed a vegetable rather than a chemical process.

The art of cookery, by exposing vegetable and animal substances to heat, has contributed to increase the quantity of the food of mankind by converting the acerb juices of some fruits into sugar, as in the baking of unripe pears, and the bruising of unripe apples; in both which situations the life of the vegetable is destroyed, and the conversion of the harsh juice into a sweet one must be performed by a chemical process; and not by a vegetable one only, as the germination of barley in making malt has generally been supposed.

Some large round austere pears were yesterday, November 20, shewn me after having been nine hours in the oven behind a kitchen fire covered some inches with water in a steam-pot. On tasting them they were sweet, and soft, and appeared to have had at least the heat of boiling water. They were replaced in the oven, and kept in it twelve hours longer; and then became nearly as sweet as syrup or treacle; which might in part have been occasioned by the
evaporation

evaporation of half the water. From this curious circumstance there seems reason to conclude, that in a degree of heat about that of boiling water the saccharine process may succeed ; and at the same time that the process of fermentation may be prevented from existing ; which I hope may induce some chemical philosopher to investigate by experiments this curious and important subject.

Some circumstances, which seem to injure the life of several fruits, seem to forward the saccharine process of their juices. Thus if some kinds of pears are gathered a week before they would ripen on the tree, and are laid on a heap and covered, their juice becomes sweet many days sooner. The taking off a circular piece of the bark from a branch of a pear-tree causes the fruit of that branch to ripen sooner by a fortnight, as I have more than once observed. The wounds made in apples by insects occasion those apples to ripen sooner ; caprification, or the piercing of figs, in the island of Malta, is said to ripen them sooner ; and I am well informed, that when bunches of grapes in this country have acquired their expected size, that if the stalk of each bunch be cut half through, they will sooner ripen.

The germinating barley in the malt-house I believe acquires not half its sweetness, till the life of the seed is destroyed ; and the saccharine process then continued or advanced by the heat in drying it ; though I have lately been informed that some grains of malt will vegetate after having been dried in the usual manner, which however may have been owing to their not having been previously suffered perfectly to germinate. Thus in animal digestion the sugar produced in the stomach is absorbed by the lacteals, as fast as it is made ; otherwise it ferments and produces flatulency ; so in the germination of barley in the malt-house so long as the new plant lives, the sugar I suppose is absorbed, as fast as it is made ; but that which we use in making beer is the sugar produced by a chemical process after the death of the young plant, or which is made more expeditiously than the plant can absorb it.

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It is probably this saccharine process, which obtains in new haystacks too hastily; and which by immediately running into fermentation produces so much heat as to set them on fire. The greatest part of the grain, or feeds, or roots, used in the distilleries, as wheat, canary seed, potatoes, are not I believe previously subjected to germination; but are in part by a chemical process converted into sugar, and immediately subjected to vinous fermentation. And it is probable, a process may sometime be discovered of producing sugar from starch or meal; and of separating it from them for domestic purposes by alcohol; which dissolves sugar but not mucilage; or by other means.

This then may be termed the saccharine fermentation, and may exist I suppose beneath or upon the earth in the beginning of some spontaneous vegetable decompositions, previous to the vinous fermentation; and may supply thus a very nutritive material to vegetation; similar to that which the embryo plants in the seeds of many fruit-trees acquire from their fruits; and to that, which the embryos in many farinaceous seeds acquire from the spontaneous change of the meal in their cotyledons; though perhaps in less quantity and purity.

2. A secondary process to this I suppose to be the vinous fermentation, in which much carbon becomes united to oxygen; and probably at the very instant of their combination, while they are yet in the form of a liquid, and not of a gas, they become absorbed by the roots of plants. The heat, which is perceived in the hotbeds, which are used for the growth of cucumbers and melons, is produced by this union of oxygen and carbon, or by the generation of some other acids, as of phosphorus, or nitre.

That this heat is owing to the atmospheric air combining with some inflammable base, and producing acidity of some kind, appears from the following experiment. A few years ago a gardener told me that a hot-bed, which he had made of tanner's bark with some
horse

horse dung and straw, was become too cold for the growth of his pots of cucumbers. He was desired simply to turn over the bed, and shake every part of it in the air with his fork, as he lightly replaced it. This was complied with, and in a few days I observed by touching a stick, which had for some hours been inserted into it, that it had acquired the usual heat of a hot-bed.

This addition of heat was doubtless acquired from the air, which was recently included in the interstices of the bed by its being turned over, broken into small pieces, and exposed to the atmosphere; whence new acids seem to have been generated, and carbon, and perhaps phosphorus and nitrogen, rendered soluble in water. Great heat is produced from the union of oxygen with those bases of acidity, which in large stacks of new hay is often known to excite real combustion; the violent fermentation of which may be partly owing to the sugar, which is deposited in the joints of grass before the seeds are ripe for their nourishment, and partly to a chemical production of sugar, as above described.

3. In the putrefactive process carbon is not only converted into carbonic acid, as above related; but there appears to be a decomposition of water, as is known by the smell of hydrogen; and it is probable, this inflammable body may unite with carbon, as in hydrocarbonate gas, and thus render them both soluble in water, and absorbable by the vessels of vegetable roots, without their passing into an acid or gaseous form, and may much contribute to the nutriment of vegetables.

4. There also appears at the end of the putrefactive process to be a junction of azote with oxygen producing the acid of nitre, which probably may contribute much to promote vegetation. This appears from the mode of procuring that acid in France and Prussia, and which might be successfully practised under every shed in our own farm-yards; as it consists in a due mixture of vegetable and animal excrements with soil, frequently turned over to expose it to the air, while

while it is defended by a shed from the sunshine and rain; which is thus at the same time adapted to produce the quickest vegetation, and to generate the nitrous acid.

The oxygen, which composes nitrous acid, is believed to adhere more weakly to its base the azote, than in the composition of other acids. On this account it so readily explodes by its junction with carbon in a given degree of heat. This loose adherence of the oxygen in nitrous acid, like that of hyper-oxygenated marine acid, and of the oxygen in the ore of manganese, and of some other metallic oxydes, may adapt them to promote vegetation by their more readily parting with this material so essential in the composition of plants.

5. From the above observations it appears, that when the soil is turned over by the spade or plough, and thus acquires atmospheric air in its interstices, and in consequence becomes warm by the production of new acids, that the seeds or plants should be inserted as soon as convenient, for the purpose of their receiving the most salutary effect of those operations. Nor should this be observed only in black garden mould, or well manured glebes, where carbon or phosphorus may be supposed to abound, and a proper disposition for the production of the nitrous acid, but in those clays also which are pure enough for the brick-kiln or the pottery.

IX. MANURES BY CHEMICAL DECOMPOSITION.

The use of fire and water contributes to increase the nourishment of mankind by rendering many vegetable materials innocuous, and others digestible in the animal stomach; and seems particularly efficacious in promoting the saccharine process, and in producing mucilage from gristles, horn, hair, and perhaps even from bones by means of Papin's digester. Whether this art could be advantageously used for the purpose of rendering manures capable of being absorbed by

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vegetable roots in a state of less decomposition, than by the flow process of putrefaction, is a question of curiosity and utility.

Sugar and mucilage are certainly absorbed by vegetables without their being resolved into the elements, from which they were composed; as appears in the sap-juice which flows from the wounds of birch and maple trees in the vernal months; which I am informed will pass into fermentation and produce wine; a process which some modern chemist affirms cannot be effected by sugar alone without the addition of mucilage. The absorption of mucilage seems to occur in the germination of many seeds, as of barley; a part of the meal of the cotyledon is evidently converted into sugar, but another part of it is probably absorbed in the form of mucilage; some of which oozes on breaking the plumula; and in the growth of those seeds, which contain oil, as in almond, hemp, rape, and line-feed, it is probable, a part of the undecomposed oil may be absorbed by the umbilical vessels of the embryos in those seeds.

It hence seems credible, that by the use of heat and water the art of cookery might furnish mucilage, sugar, and oil, from vegetable or animal materials; which might be converted into sap-juice or chyle, without their being previously reduced into their elements; and might thus facilitate the more luxuriant growth of plants, as they contribute more to fatten animals, than materials of less combination.

2. To this might be added, that the putrefactive process may be forwarded by heat in some materials by destroying the life of the material; as in roasting apples and pears, and in killing the roots of potatoes, or the seeds of corn. Thus Mr. D——, a friend of mine, had twenty strikes of potatoes, which he wished to dry on a malt-kiln, hoping to render them more like the meal of wheat, and better to preserve them during the summer-months. Whether they were sufficiently dried he did not attend to; but they were carried into a granary, and laid on heaps; and in a week or two became so putrid, that

that the smell was insufferable, his swine refused to eat them, and he was obliged to add them to the manure of the dunghill.

That potatoes, which have undergone a certain degree of heat, contribute more to fatten all kinds of animals, arises from the acrimony of their rinds being destroyed, and from their austere juices being converted into mucilage, and perhaps a part of their mucilage into starch, and are hence ready for the saccharine and oily processes of animal digestion. A very convenient method of exposing them to steam is described in a late ingenious publication of the Agricultural Society. A small boiler is set in brick work under a shed, so that the flame of wood or coal may pass spirally round it. It should be covered with a double lid of tin or wood to prevent much heat from escaping; and may have a sand-joint to keep the steam in, or a little moist clay, or even a wet flannel put circularly round the cover may answer this purpose.

Near this furnace is to be fixed a large barrel on one of its ends, with a cover on the other end; which may be occasionally opened to admit potatoes, and closed again so as to confine the steam, which is to be derived into it from the boiler by a double pipe one within the other, of tin or wood, about two inches in diameter. By these means a large quantity of potatoes may be rendered much more nutritive to animals, and I suppose to vegetables (if they were used as manure), as they may thus probably be absorbed by their lacteals or lymphatics without being so much decomposed as by the putrefactive process; and thus produce nutriment in less time, and by less labour of digestion.

If the steam could be made hotter than boiling water, which it possibly may in the vessel above described, if the water in it rises but a few inches, and the steam after it is produced, is heated above 212 degrees by the sides of the boiler above the water, round which the flame plays spirally, the steam thus made hotter might probably render the potatoes more mucilaginous or more starchy.

3. A still more effectual method of dissolving hard vegetable and animal substances, and rendering them nutritive, might be by digesting them for some time in water raised to a much greater heat than that of boiling. This is to be done in a close vessel, called Papin's digester; in which it is said, that the confined water may be made red hot; and will then dissolve hair, horns, hoofs, bones, tortoise-shell, and all animal, and perhaps many vegetable matters; which might thus facilitate their decomposition for the purposes of manures, or for the nutriment of many animals; and might even contribute to the food of mankind in times of scarcity. This vessel should be made of iron, and should have an oval opening at top, with an oval lid of iron larger than the aperture. This lid should be slipped in endways, when the vessel is filled, and then turned, and raised by a screw above it into contact with the under edges of the aperture. There should also be a small tube or hole covered with a weighted valve to prevent the danger of bursting the digester.

4. Other materials might be rendered more easily digestible, and thence more nutritive to animals, and perhaps to plants, by mechanic trituration as well as by cookery; if the labour and expence were not too great; as the grinding of grasses, straws, and farinaceous seeds into powder between mill-stones; which have been called the artificial teeth of society. It is probable, that some soft kinds of wood ground into powder, and especially when they have undergone a kind of fermentation, and become of looser texture, or boiled to destroy their acrimony, might be rendered useful food for swine or horses, and even for mankind in times of famine.

Nor is it improbable, that hay, which has been kept in stacks, so as to undergo the saccharine process, may be so managed by grinding and by fermentation with yeast like bread, as to serve in part for the sustenance of mankind in times of great scarcity. Dr. Priestley gave to a cow for some time a strong infusion of hay in large quantity for her drink, and found, that she produced during this treatment
above

above double the quantity of milk. Hence if bread cannot be made from ground hay, there is great reason to suspect, that a nutritive beverage may be thus prepared either in its saccharine state, or fermented into a kind of beer.

It may be here observed, that it is believed by some, that feeding horses with ground corn, as with the flour of beans or oats, does not strengthen them nearly so much as by giving them the same quantity of oats or beans whole. Parkinson, *Exper. Farmer*, Vol. I. p. 227. It is asserted also that soup, with the flesh-meat boiled down into a fluid mass, will give much less strength to a man, than he would acquire by eating the solid meat, of which the soup was made. The reason of both these seems to arise from the saliva being well mixed with the masticated food, and in greater quantity; which therefore becomes more animalized aliment, than that dissolved in water alone, and is more easily converted into nutriment.

In times of great scarcity there are other vegetables, which though not in common use, would most probably afford wholesome nourishment, either by boiling them, or drying and grinding them, or by both those processes in succession. Of these are perhaps the tops and the bark of all those vegetables which are armed with thorns or prickles, as gooseberry-trees, holly, gorse, and perhaps hawthorn. The inner bark of the elm-tree makes a kind of gruel. And the roots of fern, and probably very many other roots, as of grass and of clover, taken up in winter, might yield nourishment either by boiling or baking, and separating the fibres from the pulp by beating them; or by getting only the starch from those which possess an acrid mucilage, as the white briony.

The grinding of bones to powder has already been applied to agriculture, and the chopping of woollen rags; and I suppose the trituration of alabaster, and of chalk, and of soft bricks, and probably of iron ochres, manganese, and calamy, might well repay the labour;

after

after a few experiments had been instituted to determine the quantity, which should be sowed on different soils.

X. MANURES BY INSECT PROPAGATION.

1. That the continual growth and decay of animal and vegetable nature increases the quantity of such matter, as is fit for the reproduction of organized bodies, is evinced by the increasing fertility of cultivated countries; since even in these a great quantity of the annual recrements of decomposed animals and vegetables are washed by rains from the soil, and carried down the rivers into the ocean; and in many situations of soil in Africa and America, which have been but lately cultivated, there exists a wonderful fertility from the aggregate remains of vegetable and animal bodies; which have for uncounted ages arisen and perished there; and which have either left morasses, where they could not part with their superabundant water; or a fertile earth, such as in our gardens and church-yards, where the declination of the ground was more favourable.

Some countries on the contrary once highly cultivated and very populous are in process of time become deserts of sand; as many parts of Syria, and the districts about Palmira, and Balbec. This has probably been owing to the want of the necessary moisture in those warm and sandy regions; which was formerly supplied by artificial derivations of water; but which ceased, after their inhabitants were destroyed by war and tyranny; and secondly to the rapid streams occasionally poured over them by the monsoon floods; similar to those which impoverish Abyssinia and Nubia, while they fertilize the flat and showerless provinces of Egypt.

We might add, that all calcareous strata are now believed to have been produced by shells deposited by aquatic animals in the early ages of the world; and that the materials, which constitute the strata above
them,

them, have afterwards been formed by the recrements of terrestrial animal and vegetable bodies. Whence it may be concluded, that vegetables and animals during their growth increase the quantity of matter fit for the more nutritive food of organized bodies, or of that which is less decomposed; while they must at the same time occasionally form or elaborate a part of the materials, of which they consist, from the simple elements of hydrogen, nitrogen, carbon, phosphorus, sulphur, and oxygen; into which modern chemistry has resolved them by analysis.

And lastly, that vegetables can acquire nutrition from water and air alone with the carbonic acid, which floats in them, appears by the experiments of those philosophers, who have nicely enclosed the roots of some plants in pots, and moistened them with distilled water; and from hence we learn an essential distinction between vegetable and animal nature; the former can elaborate the two universal elements of water and air into nutritive juices, whereas the latter is necessitated to seek more compound nutriment, and to live upon the vegetables, which have produced it.

2. One method therefore of increasing manures may be by repeatedly propagating and destroying vegetable crops; as by raising those of quick growth, and ploughing them again into the soil during their saccharine and mucilaginous state, before they ripen their seeds; as of vetches, and buck-wheat; vicia and polygonum; and thus producing a succession of crops by the partial decomposition of the preceding ones. And it is probable that this process might be much improved by strewing lime over the recent vegetables, at the time of ploughing them in, as is shewn in No. 6. 5. of this Section.

3. Another mode by which vegetable matter may be decomposed in the summer months, and at the same time the quantity of manure increased, is by the depredation of insects, as is seen in wood, which is so far decomposing as to become tender, and is then consumed by various kinds of insects, whether it be buried beneath the soil, or exposed

posed to the air. And I suspect, that the excrement and the bodies of such insects would supply more nutriment to vegetable roots, than if the vegetable recrements were left to their spontaneous or chemical dissolution; as I suppose the bitter excrementitious powder in a filbert, and the well fed maggot, before it erodes its way out, would fertilize more barren soil than an emulsion of the kernel.

An ingenious observer of nature conveyed water on a dunghill in the summer months in such quantity, as to make a kind of semi-fluid chaos, for the purpose of animating the whole mass. It became full of insects, and was used in the autumn as manure, and he believed with much greater powers, than it would have otherwise possessed.

Hence in the summer months a manure-heap may be advantageously supplied with water for the purpose of encouraging the propagation and nourishment of myriads of insects; but in the winter season it should not be exposed to much moisture; or that which drains from it should be derived spontaneously on lower grounds, or conveyed to higher ones by pumps or water carts; as it probably consists of a solution of carbon by means of vegetable alkali; or of a mixture of it in water by mucilage; and is thought to fertilize the ground more than the other parts of the manure heap. In the transactions of some provincial Society there is an account of much fixed vegetable alkali having been obtained from the evaporation of the water, which oozed from dunghills; and M. Rouelle has observed, that fixed alkali dissolves a considerable quantity of charcoal by fusion. Fourcroy's Elem. of Chemist. Vol. IV. p. 125.

4. Another great source of insect-manure may be obtained from the myriads of small fish, by those who live near the ocean; which by mixing them with soil so as to make what is termed a compost, will much add to the fertility of the land, on which it is afterwards spread, more so perhaps than any other material except the flesh of land-animals. In China it is said that the spawn of fish in the proper season

brought to market, and purchased for the purpose of peopling the floods on their rice grounds with fish, part of which becomes large enough to be fried and eaten by the land cultivator; and the rest serves the purpose of fertilizing the soil, when the floods are drawn off, by their death and consequent decomposition.

XI. PRESERVATION OF MANURES.

1. The fertility of all countries depends on the saving and using those kinds of matter, which are fit for the reproduction of organized bodies. There is a proverb in China, that for this purpose a wise man saves even the parings of his nails, and the clippings of his hair.

One great waste of manure in this country, and in most others, is from the frequent rains washing down the diffusible and soluble parts of the soil into the muddy rivers; so that every flood from sudden showers carries into the sea many thousand pounds worth of the matter of fertility; and thus diminishes so much the food of terrestrial animals, however it may add to the sustenance of marine ones. The Delta of Egypt, and a district in South America near the foot of the Andes mentioned by Ulloa, are said by the situation of the surrounding country to be free from rain, though they have frequent dews; and to this circumstance they may in part owe their increasing fertility.

In this country the snow-floods, which occur after a continued frost, are less injurious than those from rains; as the streams of water from the upper surface of the dissolving ice flows over the under surface of it not yet dissolved; and the soil is not agitated as in rain by the percussion of the descending drops; insomuch that in snow-floods the rivers are scarcely muddy; whence these floods may be readily distinguished from land-floods by the eye, and are much less injurious.

Great attention should therefore be shewn to the preventing small

showers from washing away the soluble parts of good soil. For this purpose all hills should be ploughed horizontally, and not in ascending and descending furrows. Descending plains of grass-ground might also be laid with horizontal ridges and depressions; by which management showers will lie a few hours in the horizontal furrows or depressions, and either exhale or soak into the ground; and in very wet seasons these may easily by the spade be opened into each other, if the water is found to lie too long upon them, so as to produce too much cold by its evaporation, or too great softness by its absorption into the soil.

2. Secondly, the manures of towns and cities, which are all now left buried in deep wells, or carried away by foughs into the rivers, should be removed by a police, which is said to exist in China; and carried out of towns at stated intervals of time for the purposes of agriculture; which might be performed in the night, as is done in Edinburgh; or by means of large basins or reservoirs at the extremities of the common shores, or foughs for the reception of the manure, before it is washed into rivers. See Embassy to China by Sir G. Staunton, Vol. III. p. 308, 8vo. edit.

It has been believed by some writers in the American Medical Repository, that the pestilential fever, which has of late infested that country, was in part produced or propagated by the filth of the streets of New York. Dr. S. L. Mitchill adds to his chemical remarks on manures, “it must be welcome intelligence, that the collected mass of nuisance, which we are now with such happy success engaged in removing from the city of New York, is convertible by the powers of vegetation from poison to wholesome articles of food; and thus the purity and healthiness of the towns may contribute to the thriftiness and wealth of the surrounding country.” Medical Journal, No. I.

3. Thirdly, there should be no burial places in churches or in church-yards, where the monuments of departed sinners shoulder
God's

God's altar, pollute his holy places with dead men's bones, and produce by putrid exhalations contagious diseases among those who frequent his worship. But proper burial grounds should be consecrated out of towns, and divided into two compartments, the earth from one of which, saturated with animal decomposition, should be taken away once in ten or twenty years, for the purposes of agriculture; and sand or clay, or less fertile soil, brought into its place.

A great rise of the soil, from the remains of the bodies entombed in it, is seen round the churches of almost all populous towns; so as to have rendered it necessary to descend by several steps into those churches, which were originally built so as to require steps to ascend into them; as may frequently be seen by the base of the architecture. Nor would the removal of this earth, if the few bones, which might be found, were again buried for a further decomposition, be likely to shock the relations of the deceased; as the superstition concerning the earth, from which we rose, and into which we return, has gradually vanished before the light of reason; as occurred about thirty years ago in removing much rich earth from the clove of the cathedral at Lichfield, and more lately in changing a burying ground at Shrewsbury; both which were executed without superstitious terror, or popular commotion.

4. Fourthly, a great waste of the materials of fertility occurs in all countries, and cannot easily be avoided, in the consumption by fire of so much wood instead of coal. Whence the mucilage, and other nutritious juices, which exist in the fire-wood, are decomposed into their elements; and the carbon united with oxygen is diffused in the atmosphere, and in part carried by the winds into the surrounding ocean; instead of the manures occasioned by the slow decomposition of it upon or beneath the soil, or by the depredation of insects; which might supply less decomposed nutriment to the absorbent roots of plants.

This may be more easy to conceive, if we compare the little vege-

table nutriment, which could be derived from the small quantity of ashes left from a cart-load of burnt-straw, with that which would arise from the same quantity of straw mixed with some animal recrement, and made into a manure heap. A still greater diminution of useful manure would be made by burning shavings or raspings of horn, or woollen rags, or hair, or flesh; as a nutritive mucilage would be thus decomposed into its elements, which might otherwise have been gradually dissolved beneath the soil, and absorbed by the roots of vegetables nearly in an unaltered state; as jellies and mucilage are known to be drank up by the lacteals of animals; and, when drank in too great abundance, to appear almost unchanged in their urine.

It must hence appear, that the numerous fires of a great city, if supplied with wood instead of coals, as in Paris, must very much impoverish a great part of the country which supplies it; not only in the necessity of using large tracts of land for the growth of fire-wood, but also because so small a part of it returns as manure. There is a provident adage of general benevolence, "Burn nothing which any animal will eat;" that is, "Burn nothing which may nourish animals by its digestion in their stomachs." May not the same benevolent idea be extended to the vegetable world, and say, "Burn nothing which may nourish vegetables by its slow decomposition beneath the soil, which constitutes their stomachs."

5. It may be a matter of use as well as of curiosity to ascertain the situations and circumstances most favourable for promoting the spontaneous decomposition of vegetable substances; which may consist perhaps in the due quantity of air, water, and heat, with a sufficient proportion of animal substances, and finally an admixture of lime toward the end of the process.

1. In a cellar covered with an arch of bricks, and closed with a very strong door, I once observed, that a deal shelf two inches in thickness was decayed, so as to fall down with some wine bottles on

it,

it, in about four years. This sudden decay I believed to have been owing to the unchanging moisture of the board, and at the same time to its exposure to unchanged air without the power of much exhalation; by which a slow fermentation was induced, and a consequent slow putrefaction, unchecked by the extremes either of heat or cold.

For the same reason I suppose the wooden supporters of bridges decay first just above the surface of the water; and pieces of timber buried but a few inches under ground, which are there exposed to the influence both of water and air, go quicker into fermentation, and consequent putrefaction, than those pieces of timber, which are many feet buried beneath the soil, or immersed deep in water; which in that situation continue unchanged for ages. The same seems to occur in the vinous fermentation, which is instantly checked, if not totally stopped, by bunging the barrel, or corking the bottle, which contains it, and thus precluding the access of atmospheric air.

2. From hence it may be concluded, first, that the vegetable and animal substances, which we wish soon to become decomposed by the fermentative and putrefactive processes, should be exposed to an uniform moisture, though not covered deep with water; as is generally practised in the first part of the preparation of hemp or flax, which is designed to dissolve the mucilage, and the cellular membrane of those vegetables, without injuring the ligneous fibres. And that they should be so far accumulated as not too much to exhale; yet not to lie in such large heaps, as entirely to preclude the access of air from the interior parts of them.

The manures of great farms should therefore be occasionally removed from the fold-yards, or large reservoirs of it, and laid in small heaps not only to increase its surface exposed to the external atmosphere, for the purpose of exciting greater fermentation, which is a slow combustion; but also that air may be imprisoned in the interstices of these manure-heaps, as mentioned in No. 8. 2. of this Section.

It should then be used on or in the soil, as it afterward loses much of its nutritive qualities by evaporation, or sinking into the ground, or draining away.

3. A due degree of heat is necessary for the commencement of fermentation and putrefaction, as both vegetable and animal materials, as fruit or flesh, may be preserved for years if kept in an ice-house below the freezing point of 32. And also, I am told, if they could be kept in an uniform degree of heat above the boiling point of 212. After the commencement of either of these processes a quantity of heat is evolved from the combination of the oxygen and carbon, which contributes to forward the processes by promoting the union of the next particles of oxygen and carbon; which may thence be compared to a slow combustion, or to a gradual explosion of gunpowder.

This heat therefore should be managed with some address, as a great quantity of it would calcine or evaporate too much of the materials, and leave the remainder a less profitable mass; as happens, I am informed, to some parts of those heaps of manure, which are used in the manufactory of white lead; while on the contrary, when the heat is too small, as in severe frost, these processes of decomposition will not commence, or may be stopped in their progress. In the former case, where the heat is too great, it may be checked by covering the whole manure-heap with soil and turf, and thus preventing the access of air. And when the heat is too small, as in old hot beds, it may be renewed or promoted by turning the heap over with the spade, and thus confining a new quantity of air in its interstices. On these accounts it appears, that in the vernal and autumnal months these processes must succeed better than in the winter or the summer ones.

4. Toward the end of the putrefactive process the materials should be repeatedly turned over with the spade, not only for the purpose of simply exposing their interior parts to the atmosphere, but also of including

cluding air in the interstices; as the union of carbon with oxygen, and probably of azote with hydrogen, seems thus to be occasioned; by which the three last of these elements may change from a gaseous state into a fluid one, and thus become absorbed by vegetable roots.

Lastly, I conclude that in general the manure heap before stables, or in the fold-yard, should be placed on a gently rising eminence, with a basin beneath it, that the superfluous water, which would otherwise prevent the fermentation of the straw, may drain off and be there received; and that into this basin, as often as a fluid appears in it, some earth, or weeds, or leaves, or saw-dust, or other vegetable or animal recrements should be thrown; the fermentation and putrefaction of which will be thus forwarded, and the carbonic draining from the manure-heap will not be lost.

5. The admixture of lime with this carbonic soil is found by daily experience to produce the most fertile compositions for the growth of vegetables, and for the production of nitre. The great use of nitrous acid in vegetation has long been acknowledged, and that of hyper-oxygenated marine acid appears probable from recent experiments; and would seem to be occasioned by the more loose adhesion of the oxygen in those acids to their respective bases; which may therefore in its fluid state be more readily absorbed by vegetable roots. One use therefore of the admixture of lime in such a compost of soil and manure is to arrest the nitrous acid, as it is formed, and by making a calcareous nitre, prevent its exhalation, or its easy elutriation from the other materials.

6. A principal circumstance for the quicker and more perfect decomposition of vegetable recrements is a due quantity of animal matter, and their being properly mixed together; as appears from the early experiments of sir John Pringle and Macbride, and by daily experience. There is nevertheless great neglect in this respect in all those farm-yards, where the swine have their food in fixed stone-troughs,

troughs, from which the refuse is occasionally washed or swept. Whereas if wooden moveable swine-troughs were always placed on the summit of the heaps of dry straw, the quantity of their swill, consisting of broth, whey, and other vegetable and animal matter, which these animals waste in their contention for it, would generate early putrefactive processes; besides their mixing the substances well together with their feet, and adding to it their urine and ordure.

Besides this inattention to the manure-heap in many houses the washings of boilers, and milk-pans, and dishes, as well as the soap-suds, which are all of them manures of the most productive kind, are thrown into the common sewer, instead of being derived or carried to the garden or the straw-yard.

7. Another inattention to the production of manures concerns the heaps of common weeds, and of dock-roots, and of cabbage-stalks, and the roots of twitch-grass; which improvident farmers and gardeners frequently throw into the high roads, or consume with fire; and which if laid on heaps, and occasionally turned over, and covered with soil, will quickly die, and pass into speedy fermentation from the sugar and mucilage, which they contain; and if to these a portion of lime be added, I am informed by one who made the experiment, that the whole was decomposed in a short time, and manure of the best kind was the product.

The same should be practised with the leaves which fall in autumn on grass land, especially from those orchards, or hedges, or from gooseberry-trees, which have been infested with caterpillars; since I am told the eggs of a future race of these insects are frequently deposited on the leaves, and hatched on or beneath the soil in the ensuing spring. These therefore should be removed from the roots of such trees, and converted into manure by the process above mentioned.

Along with the weeds and leaves above mentioned I should strongly recommend to the industrious agricultor to collect the water-plants
which

which grow in great abundance in lakes and rivers, for the purpose of manure; which at present are employed to no advantage. These might be moved twice a year, as it is probable that these vegetables in their younger state, as the typha, or cat's-tail; the butomus, or flowering-rush; nymphæa and alisma, as well as many other aquatic plants, would give better manure, or sooner become sufficiently decomposed, during their more saccharine and mucilaginous state, than when they have acquired more fibrous leaves, and more woody stems.

By thus exposing the roots and tops of weeds to fermentation, their seeds would also be destroyed as well as the vegetative power of their roots; and on this account the hay-seeds collected from stacks, which have fermented too violently, so as to become black by this slow combustion, are frequently so much injured as not to vegetate, to the great disappointment of the sower, a circumstance which also sometimes occurs in stacks of wheat, as mentioned in Sect. XVI. 7. 1.

8. Lastly, peat, so well understood and so strongly recommended by Lord Dundonald, is too much neglected in agriculture. The peat or turf, which constitutes the solid parts of morasses, as it consists of vegetable fibres in different states of decomposition, may be laid on clayey or sandy soils with the greatest advantage; and ought to be considered as an inestimable treasure to the farms in its vicinity. Or it may previously be laid on heaps, and thus mixed with air and drained from water for further decomposition, with or without the addition of lime.

XII. APPLICATION OF MANURES.

Two questions of importance here present themselves. As the spontaneous or chemical changes of manure-heaps in farm-yards gradually progrede from the saccharine and mucilaginous commence-

ment through a great variety of other fermentations; which can only be named from the principal material, which each of them produces, as carbonic acid, alcohol, vinegar, volatile alkali, hydrogen, nitrous acid, and finally carbonic earth. At what era or stage of this decomposition of vegetable and animal substances can they be most advantageously applied to the purposes of agriculture? and secondly, at what time of the year?

1. In respect to the era of the progress of the decomposition in manure-heaps, in which they may be most advantageously applied in agriculture, the particular purpose of that application must be attended to. Where they are designed to be spread on the surface of grass lands, as a top-dressing, the accumulations of vegetable and animal recrement should be permitted to go through the various spontaneous processes of decomposition, which begin with the saccharine and mucilaginous state, and end with the production of carbonic earth, with many kinds of intermediate fermentations, if they may be so called, which accompany or succeed each other, and which I believe to be more in number than have had names applied to them.

But that less of the fertilizing materials, whether of soluble solids, or of fluids, or of gasses, may be lost in these series of fermentations; it is a very advantageous management to cover them with soil, when the first fermentation is advanced, as is known by the production of considerable heat; or when the putrefactive one has commenced, which is known by the smell of volatile alkali, or of hydrogen. By this method the too great rapidity of these fermentations is checked, and the fluid part of the manure is retained by the addition of the soil below, and the gaseous part by that above; and if to this be afterwards added a proportion of lime, which by uniting with the nitrous acid may retain it from exhalation or from alluviation, every thing is preserved that art can accomplish.

Where manure-heaps are to be ploughed into clayey soils, which are liable to become too solid and impenetrable to the root-fibres of seeds,

feeds, as of wheat; or where knobby or bulbous roots are to be inserted to produce other knobs or bulbs beneath the soil, as potatoes; it is probably more advantageous to bury the manure in a less decomposed state, while some of the straw retains its form; as such parts by their slower decomposition will longer prevent the super-incumbent soil from becoming too solid; and though they will in this situation require some time before they will be perfectly decomposed, and reduced to the black carbonic earth; yet they will in the end totally decay, and give the same quantity of nutriment to the roots, though it may be more gradually applied.

2. In respect to the time of year those manures, which are to be ploughed or dug into the ground, should be used immediately before sowing the seeds or setting the roots, which they are designed to nurture; because the atmospheric air, which is buried along with the manure in the interstices of the earth, and which for many weeks, or even months, renders the soil loose, and easily impressed by the foot on walking on it, gradually evolves by its union with carbon a genial heat very friendly to vegetation in this climate, as well as the immediate production of much fluid carbonic acid, and probably of a fluid mixture of nitrogen with hydrogen, which are believed to supply much nutriment to plants.

But those manures, which are designed to be spread on the surface of grass-land, which is called the top-dressing, are best applied, I suspect, in the early spring; and should be dispersed over the soil almost in a state of powder, or in lumps of very loose cohesion; as at this time the vernal showers wash them into the soil; and they are applied to the roots of the grass, before their essential parts are diminished by winter rains or by summer exhalation. There are some in Derbyshire, who spread manure even on the meadows, which are annually overflowed by the Trent or Derwent, at the end of summer, or as soon as the grass is mowed and removed; which appears to be an improvident management, since the aftermath, or autumnal grass,

is thus rendered unpalatable to the cattle; and the winter rains, or the vernal floods, which generally occur with the return of the south-west winds, after the season of frost ceases, must wash away a great part of it.

In respect to the most economical manner of using manures in agriculture Mr. Parkinson asserts, that one great advantage of the drill-husbandry consists in putting the manure into drills, which he directs to be made at two feet distance from each other. He sows wheat, beans, peas, cabbages, on this manure, and affirms, that four loads of manure on an acre in this kind of husbandry is equal to sixteen loads in the usual way of spreading it over the whole of the field. *Experienced Farmer*, Vol. I. p. 32.

3. A third question here presents itself, if the recrements of vegetable and animal bodies buried a few inches beneath the soil undergo the same decomposition, as when laid on heaps in farm-yards. And though this is accomplished more slowly, yet it is attended with less loss of carbonic acid, and of volatile alkali, and of hydrogen, and of the fluid matter of heat; all which are emitted in great quantity during the rapid fermentations of large heaps of manure, and are wasted in the atmosphere, or on unprolific ground; would it not in general be more economical to bury such vegetable and animal matters beneath the soil without a previous fermentation and putrefaction?

In answer to this it must be observed, that in some cases the use of recent vegetables ploughed into the earth is found of advantage, as in sandy soils buck-wheat, or vetches, are sown, and the crop ploughed in, before it ripens its seeds. In this circumstance the recent crop is buried in its saccharine and mucilaginous state, which must undergo indeed a slower fermentation, without being mixed with animal substances, but no part of the organic matter, nor of the fluid heat, is lost to the purposes of new organization.

So in the cultivation of clayey lands, whose tenacity is too great;

or

or where knobby roots, as potatoes, are to be inserted for the production of other knobby roots beneath the soil; long muck, as it is called, or such which is only so far decomposed as to dissolve the mucilage or more tender vessels or membranes, but in which the form of the fibrous or ligneous parts of the straw remains, is recommended above; and may in these situations perhaps be ploughed into the ground even in their most early state, when rejected from the stable or cowhouse, before the commencement of their spontaneous dissolution.

So also in gardens, which are already fertile, and do not want the immediate assistance of mature manure, it may be more economical to bury the weeds, as the ground is dug, than to convey them to a manure-heap, and replace them after a twelvemonth's decomposition.

But where a luxuriant crop is immediately wanted, a manure-heap towards the end of the putrefactive process by being recently interred in the soil, which is immediately to be sown or planted, has this great advantage; that the carbonic acid is presently formed by the mixture of atmospheric air with the carbon of the manure; which exists therefore in its fluid, not its gaseous state, and is thence more readily absorbed. Secondly, ammoniac is produced, and nitre, and hydrogen probably is mixed with nitrogen; and these also, I suppose, exist at first in their fluid, not in their gaseous state. And thirdly, from these combinations a genial degree of heat is evolved, which so much assists the vernal growth of vegetation.

And where manure is to be used as a top-dressing, it is necessary, that it should be in a state of powder, or in small lumps of loose cohesion, as mentioned above; that it may be easily washed by rains to the roots of the grass, or that the young stems of grass may readily shoot themselves through it; whence mature heaps of manure are for this purpose necessary; and on this account any adhesive manure,

nure, as cow-dung itself, should be weekly gathered from grass-ground, where cattle are nourished, and laid on heaps with soil, or straw, or weeds, to ferment or putrefy ; till it becomes less tenacious, and can be profitably replaced in the ensuing spring.

Finally, I suspect the most economical method of disposing of the straw and dung from the farm-yard would be, as soon as a dark coloured water drains from the heap, by which much loss is sustained, to carry the refuse of the stable and cow-house, as frequently as convenient, to the ground, where it is designed to be employed ; and there to mix it with earth in heaps of proper size, and to cover them likewise with soil ; and by these means I suppose the whole process of decomposition may be carried on with very little loss ; and by the addition of a greater or less quantity of soil that the era of complete or most profitable decomposition of the compost may be managed, so as to coincide nearly with the time it may be wanted.

4. Fourthly, it may be asked, what kinds of manure contribute most to the luxuriant growth of vegetables ? In answer to this it may be said, that as plants are inferior animals, and are furnished with absorbent vessels in their roots correspondent to the lacteals in the stomach ; that the same organic matters, which by their quick solution in the stomach supply the nutritive chyle to animals, will by their slow solution in or near the surface of the earth supply the nutritive sap-juice to vegetables. Hence all kinds of animal and vegetable substances, which will undergo a digestive process, or spontaneous solution, as the flesh, fat, skin, and bones, of animals ; with their secretions of bile, saliva, mucus ; and their excretions of urine, and ordure ; and also the fruit, meal, oil, leaves, wood, of vegetables, when properly decomposed on or beneath the soil, supply the most nutritive food to plants.

Secondly, the chyle of all animals is similar to the sap-juice of all vegetables in this circumstance, that they both contain mucilage and
 7 sugar,

sugar, and seem only to differ in this respect, that the chyle of animals also contains oil, which being mixed with the mucilage gives it its whiteness like milk. Hence those matters must supply nutriment most expeditiously to vegetables, which contain mucilage and sugar, or produce them with the least decomposition, as the jellies from the shavings of horns, from hair, woollen rags, and the saccharine matter of sweet fruits, roots, kernels, seeds; and in the same manner these things with the addition of oil are most expeditiously nutritive to animals.

Thirdly, such materials as contain in solution those simple substances, which constitute a great part of vegetable bodies, as carbon, which is found in most earths; and oxygen, hydrogen, and nitrogen, which are found in water and in air; and from hence we may conclude, that whatever material has constituted a part of living organic bodies, may again constitute a part of them; and that with more expedition, if they can be used without being decomposed into their primary elements.

Mr. Bewley, the Norfolk philosopher, said to a friend, who was riding by his side, that when he wanted a whip, he habitually looked for a dead stick in the hedge, unwilling to pluck off a leafy branch, and destroy so many living buds. He might have added, that to burn a hair or a straw unnecessarily diminishes the sum of matter fit for quick nutrition by decomposing it nearly into its elements, and should therefore give some compunctions to a mind of universal sympathy.

It would seem therefore, that long roots fixed into the earth, and leaves innumerable waving in the air, were necessary for the decomposition and new combinations of water and air, and the conversion of them into saccharine and mucilaginous matter; which would have been not only cumbrous but totally incompatible with the locomotions of animal bodies; for how could a man or quadruped have

have carried on his head or back a forest of leaves, or have trailed after him long branching lacteals terminating on the surface of the earth? Animals therefore subsist on vegetables; that is, they take the matter so far prepared, and possess organs to prepare it further for the purposes of greater sensibility, and of higher animation.

S E C T. XI.

OF DRAINING AND WATERING LANDS.

- I. 1. *Morasses are in high or low situations. 2. Springs rise from the summits of mountains, pass between the strata. 3. Strata of the earth about Derby, and at Lichfield, and the springs. 4. Plains formed in vallies. 5. Wall-springs intercepted by ditches, sunk perpendicular to the sides of the hills. 6. By boring holes at the bottom of such ditches. 7. Use of ditches, where the wall-springs cannot be intercepted. 8. Holes through clay into a sand-stone beneath. 9. Deep springs rise highest, when bored into. 10. Many springs may be raised higher than their sources. 11. Enlarging the bottom of wells increases the water in them. 12. Springs discovered on one side only of some mountains. Discovered by evening mists. By morning rime. By aquatic plants. Warm springs.* II. 1. *Draining morasses, where there is no fall. 2. In the craters of ancient volcanoes. 3. In countries of marble, granite, or quartz. 4. Fens below the level of the sea. Should be surrounded with dikes. 5. Uses of aquatic plants.* III. 1. *Of flooding lands. 2. Ice preserves the grafs beneath. The French bored holes in the ice. 3. Advantages of flooding recapitulated. It destroys rushes. Saves manure. 4. Cautions to be observed. Flooding not injurious to health. Vicinity of running water wholesome. 5. Flooding lands might be performed to a great extent. By rivers, springs, land-floods, and machinery. Hiero's fountain. Horizontal wind-mill, and centrifugal pump.*

I. 1. THE great quantity of water required for healthy vegetation is treated of in Sect. X. 3. 1. But as all extremes are injurious, too much water becomes pernicious to all except aquatic plants. Whence the necessity of draining those lands, which too much abound with moisture; the art of which is better understood, since the knowledge

of geology has been studied, and in some measure diffused amongst the people.

Lands in respect to the method of draining them may be divided into two situations; those which lie so high, that the water can descend from them, if it be properly collected and conducted; and those which lie so low as to command no fall, some of which are even below the level of the sea.

2. In regard to the former it generally happens, that the waters from the springs beneath the soil have not a free passage to the rivers in their vicinity; the nature of springs should therefore be previously understood. Many modern philosophers have endeavoured to shew, that all the continents and islands of the world, as well as the hills, which emboss their surfaces, have been raised out of the primeval ocean by subterraneous fires. This appears from the quantity of sea-shells, which form innumerable mountains; and from the fissures in the rocks, of which they consist; the quantity of volcanic productions all over the world; and the numerous remains of craters of volcanoes in mountainous countries.

Hence the strata, which compose the sides of mountains, lie slanting downwards; and one or two or more of the external strata not reaching to the summit, when the mountain was raised up, the second or third stratum, or a more inferior one, is there exposed to day. This may be well represented by forcibly thrusting a very blunt instrument through some folds of paper, a bur will be raised with the lowermost leaf standing highest in the center of it. Or if at the original elevation of an extensive mountain the lowest stratum should not at first stand higher in the center of the summit, it would in time become so by some of the upper strata of the mountain being gradually washed away by rains into the valleys or rivers. On this uppermost stratum, which is colder, as it is more elevated, the dews are condensed in large quantities; and sliding down pass under the first, or second, or third stratum, which compose the sides of the hill;

hill; and either form a morafs below, or a weeping rock by oozing out in numerous places; or many of thefe lefs currents meeting together burft out in a more copious rill.

The immediate caufe of fprings confifts therefore in the condensation of the atmofpheric moiſture, during the night principally, by the greater coldnefs of the fummits of hills, which is explained in detail in the Botanic Garden, Vol. I. additional note 26. The water thus condensed on the fummits of hills defcends between the ſtrata of the incumbent ſoil, ſometimes for many miles together; but generally from the neareſt eminences into the adjoining vallies.

3. Thus there is a ſtratum of marl, which I have obſerved on the ſurface of the lands about Derby, which extends many miles in moſt directions. This ſtratum of marl is of various thicknefs from 10 to 150 feet, and beneath it lies a ſtratum of ſand, which is alſo of various thicknefs from a few inches to fix or eight feet, and of various degrees of induration; and beneath this lies another ſtratum of marl to an unknown depth. On the top of Radborne common, about five miles north-weſt from Derby, the ſandy ſtratum is quite looſe, and riſes above the ſtratum of marl, which is deficient at the ſummit of the hill. Three or four ſtrong ſprings of water burft out on the ſides of this hill, which thus originate from the moiſture of the atmofphere condensed on the cold ſummit, and paſſing through the ſandy ſtratum between the two ſtrata of marl.

In the road to Duffield, about two miles north of Derby, the ſand-ſtratum is cemented into ſtone, as well as in ſome ſituations near Radborne-common above mentioned. This ſtratum of ſandſtone is ſome feet in thicknefs, and lies four or five yards deep, beneath the upper ſtratum of marl, dividing it from the lower one. At Normanton, about two miles ſouth from Derby, the ſand-ſtratum conſiſts of a looſe ſand, ſo white and pure, that I imagine it might be uſed in the manufacture of flint-glaſs, and lies about twelve feet deep, beneath the upper ſtratum of marl, dividing it from the

under one. In the town of Derby on boring with design to sink a well, after having passed about thirteen yards through marl, some sand was brought up by the auger, and water followed, as related in the *Philos. Transact.* Vol. LXXV.

The dews therefore, which are perpetually condensing on the summits of these hills, descend beneath the upper and under strata of marl, through the thin stratum of sand, which divides them, and form St. Alkmund's well, and many other springs in the vicinity of Derby; and probably all those which supply the wells within the town.

But there is a situation, where the manner of the production of springs is most agreeably visible; it is about a mile from the city of Lichfield, near the cold bath erected by sir John Floyer, in a beautiful piece of ground, which was formerly Dr. Darwin's botanic garden.

In this place a grotto about six yards wide and ten long has been excavated on the side of a hill consisting of siliceous sand-stone with this peculiar circumstance; that the upper stratum of the sand-rock, which is there about five feet thick, is divided from the lower stratum of it by a sheet of clay not more than three or four inches in thickness; on the upper surface of this sheet of clay, between the lips of these rocks, a perpetual dribbling of water oozes quite round the grotto, like a shower from a weeping rock. Such sheets of water having been often observed to slide between the strata of the earth almost horizontally, like the horizontal joints of a stone-wall, have, I suppose, given the name of wall-springs to them, to distinguish them from pipe-springs, or such as burst out in a single rill.

Thus this thin sheet of clay prevents the water from sinking into the lower stratum of sand-stone; and produces other copious springs, which are collected at about half a mile's distance, and conveyed by leaden pipes to the cathedral close of Lichfield, which is thus supplied with water of uncommon purity, which contains no calcareous

ous earth, owing to its passing through siliceous sand over a stratum of clay, and which would be a treasure to the paper-mill or the bleach-yard.

4. One other circumstance in the present conformation of the earth is necessary to be mentioned; which is, that at the time when the mountains were raised all over the world by deep volcanoes, or by central fires, some parts of the summits of many of them, and of their steeper sides, rolled down again into the new formed vallies. And secondly, that since that remote time the recrements of vegetable and animal bodies have continually been washed down from the eminences by showers, and have contributed gradually to accumulate in the vallies, and to form the plains, which exist on the sides of rivers. This appears from the tin ores found in the vallies in Cornwall in loose pieces similar to those in the proximate mountains; and from the black carbonic soil, or morass-turf, found in most vallies.

5. From these clear ideas of the strata of the earth, and of the streams of water, which slide between them, and form what are termed wall-springs, it is easy to conceive, that the best method of preventing the vallies at the bottom of hills from being too moist must be by cutting a long horizontal ditch into the side of the mountain to intercept the water, just before the level land of the valley commences; and thus to carry away the water before it comes upon the plain beneath.

For this purpose at the foot of the hill where the plain, which is too moist, commences, some auger-holes should be bored to find the depth of the springs, that is to find the thickness of the upper stratum of the soil. If this be only four or six feet, an horizontal ditch should be cut along the bottom of the mountain to intercept the water; which must then be carried away by one or more other ditches opening into this, and conducting the water so collected into the neighbouring rivulet.

As the strata, between which the water descends in forming these springs,

springs, have generally the same inclination as the surface of the hill, or nearly so; it follows, that the holes should be bored, and the ditch cut, not vertically downwards, as is the common practice, but perpendicular to the surface of the mountain; as by that means the second stratum will sooner be arrived at; as shewn in Plate V. at the end of this Section.

6. But if on cutting a ditch five or six feet along the bottom of the hill perpendicular to the rising plain, which forms the side of it, the upper stratum be not cut through; and in consequence no water oozes into the bottom of the ditch; it is then proper to bore other holes at the bottom of this ditch some yards deeper, or till water rises up through them into the ditch, if it can be so discovered. Where this succeeds, many holes should be bored, and the water received into the ditches, and conducted into the adjacent river; for the water will then rise into the bottom of this ditch six feet below the wet surface of the valley, and thus flow away, rather than rise up from the lower wall-springs, or apertures of the stratum, through the incumbent soil to the surface of the valley, which is so many feet higher. This well understood is the great secret for draining those grounds, where the springs can not be cut into simply by a ditch.

This method has been some years practised with success by Mr. Elkington, but was previously used and explained by Mr. Anderson, as he asserts in his introduction to Vol. III. of his *Essays on Agriculture*, who sunk a hole into the earth at the bottom of a ditch in the year 1764, and the water rose six feet above the surface of the ground, and has continued to flow with less violence ever since that time.

It should here be noticed, that where the water rises with great force through holes thus bored into a deep stratum, it is liable to bring up along with it much sand, so as sometimes to obstruct its passage; which sand in this case must frequently be removed for a few days by the reapplication of the auger. Of this a remarkable in-

stance is published in a late volume of the Phil. Transf. by Mr. Wuliamy, who sunk a well 236 feet deep and four feet wide; and, on then boring a few feet lower with a five-inch borer, so much sand arose with a violent stream of water, as to fill up the whole well; which was repeatedly cleared away by buckets in its fluid state, and at last the water ran over the surface to the amount of forty-six gallons in a minute.

The manner of making these ditches narrower, as they descend, by spades of an adapted breadth; and of making the lowest part narrower than any other part, so that the shoulders or edges of it may support stones, or faggots, to cover the whole at a small expence without obstructing the currents of water, are obvious to the workmen. In many situations hollow bricks, or ridge-tiles, or old pieces of plaster-floors, may be worth the additional expence of providing them.

7. There may nevertheless be found situations, where the first stratum of earth may be too thick to be easily penetrated; or where the water, condensed from the atmosphere on the summits of the hills, may slide between the second and third, or between the third and fourth strata, which form the sides of those hills, owing to a deficiency of so many of the strata at the summits of them; and hence that it may lie too deep to be easily arrested by a ditch, or by boring; and yet by its being dammed up by the materials, which form the level plain of the valley, may rise up through those materials to the surface, and form boggy or morassy ground.

In these situations the common unskilful method of draining may be usefully employed; which consists in cutting many ditches four or six feet deep across the bog or morass; and covering them, so that the water may have no obstruction in passing along them; which may thus, as it rises from below, be in part collected and conveyed away; though less advantageously than where the springs can be intercepted.

Another

Another method of draining moist meadows has been by making or opening drains almost annually by a large plough with two converging coulter, and other adapted parts, for the purpose of cutting both the sides of a ditch at the same time, and turning out the intervening turf and soil. These large ploughs have been kept in some parishes, and drawn over moist commons by twelve or twenty horses, to form parallel ditches.

Mr. Adam Scott has invented for the same purpose what he terms a mole-plough, which consists of a coulter fifteen inches long, and two and a half wide, to cut the sward; and behind this an horizontal cone of cast iron twenty inches long, and two and a half diameter at the base, to the middle of which is fixed an upright bar two feet long, and three inches and a half broad, with a sharp edge. As this cast iron cone is drawn along six or eight inches beneath the turf in moist lands, either in the spring or autumn, in many parallel lines, the water for a considerable time is conveyed away, and no injury done to the surface; which thus seems to be an useful machine, and may be well managed, I am informed, by six or eight horses. In very moist lands, or at very moist seasons, if more horses be used, their feet will not sink so deep into the turf, as each horse will draw less; or a contrivance of adding broader shoes of wood to the horses like the snow-shoes of higher latitudes, might answer this purpose. See *Transact. of Society of Arts*, Vol. XV.

8. There are nevertheless some situations, where the water is conveyed beneath the first stratum on a thin bed of clay over a porous sand-stone beneath it; as in the grotto at Lichfield above described. In these situations by boring many auger-holes, or by sinking wells, through the stratum of clay the water will penetrate the sand-stone beneath it; and either pass away by the porosity of this kind of stone, or by the cracks or joints which are always found in it; of which the horizontal joints were formed at the time of the production or accumulation of the sand beneath the sea, which was then formed in
horizontal

horizontal strata ; but the vertical cracks were made at the time of its elevation by subterraneous fires. In these vertical fissures the ores of lead, ponderous earth, and calcareous spars, are found in the limestone rocks of Derbyshire ; and those of tin, and quartz, in the granite rocks of Cornwall.

9. The knowledge of this part of geology concerning the formation of springs may be employed for many useful purposes ; thus where the wall-springs, or water-conducting strata, lie so deep as not to be accessible at a small expence ; they generally exist between the second and third, or between the third and fourth strata ; which rise into day higher on the summits of the adjacent mountains than the first stratum ; and hence, when they are bored into, the water will rise higher, than when it is found beneath the first stratum only ; which generally becomes deficient on lower parts of the adjacent eminences of the country.

Thus where water, descending in high columns between the strata of mountains, is dammed up below by the materials, which fill up the vallies ; if a hole be bored in the valley deep through the incumbent soil and strata, it frequently rises much above the source of the new aperture, and sometimes above the surface of the ground. In sinking the king's well at Sheerness the water rose 300 feet above its source in the well, as related in *Philos. Transact.* Vol. LXXIV. And at Hartford in Connecticut there is a well, which was dug seventy feet before water was found ; and then on boring an auger hole through a rock the water rose so fast, as to make it difficult to keep it dry by pumps, till the hole could be blown larger by gunpowder ; which was no sooner accomplished, than it filled, and run over, and has been a brook for near a century. *Travels through America*, Lond. 1789. Lane.

In the town of Richmond in Surry, and at Inskip near Preston, in Lancashire, I am informed, that it is usual to bore for water to a certain depth ; and that when it is found in both those places, it rises

so high as to flow over the surface. And there is reason to conclude, that if similar experiments were made in many other places, such artificial springs might be produced at small expence, both for the common purposes of life, and for the great improvement of lands by watering them.

10. Another deduction, which may be made from this knowledge of geology, is, that many springs of water, which lie too low for serving a house, or street, or town, or for watering higher grounds for the purposes of agriculture or gardening, may in many situations be dammed up many feet with little or no loss. Thus when the new bridge was building at Dublin, Mr. G. Semple found a spring in the bed of the river, where he meant to lay the foundation of a pier; which by fixing iron pipes into it he raised many feet; and in boring a hole near the Derwent in Derby about fifteen yards deep, the water rose above the surface of the ground, and has continued to flow now for above twelve years in rather an increasing quantity. From having observed a valley north-west of St. Alkmund's well near Derby, at the head of which that spring of water once probably existed, and by its current formed the valley, (which current in after times found its way out in its present lower situation), I suspect, that St. Alkmund's well might by building round it be raised high enough to supply many streets in Derby with spring water, which are now only supplied with river water.

11. A third deduction from the knowledge of this geology concerning the production of springs teaches, that by enlarging the bottom of a well, where the water oozes from between the surrounding strata in too scanty a supply, a proportionally greater quantity of water may be procured. The hole near the river Derwent in Derby above mentioned, is about an inch and a half in diameter, and was bored about fifteen yards deep through the uppermost stratum of marl into the sand beneath it, and supplies Dr. Darwin's house with two or three hogheads of water a day. And Mr. Strutt near St. Peter's

ter's Bridge has sunk a well for the use of his steam-engine about 200 yards from the former, which passes through the same upper stratum of marl, and is three feet in diameter at the bottom, and supplies, when required, a hundred hogheads in a day.

12. The knowledge of this part of geology leads to another useful purpose, the discovery of springs; concerning which some have pretended to possess secret or mystical intelligence both in England and in France. When the eminences of a country were raised out of the primeval ocean by subterraneous fires, some of them were raised nearly equally on all sides, like the limestone mountain at Breedon in Leicestershire; in which the central stratum may be seen to stand nearly erect or vertical, and those on all sides at considerable inclination. Other mountains were abruptly broken off on one side only from the adjoining earth, like those which form the high torr at Matlock; which rise with one of their sides perpendicular as a wall by the Derwent side; so that the strata of the former of these mountains may be represented, as before mentioned, by the bur, which would be made on some folds of paper, if a very hard blunt instrument was thrust through them; and the latter by raising up one edge of such folds of paper, so as to incline the whole of it at some angle with the horizon.

As the springs consist of the water, which slides between these inclined strata; it is evident, that in some eminences of ground they are only to be met with on one side of the mountain; and in other eminences of ground on all sides of it. In searching for springs therefore attention should be given to the inclination of the strata of that part of the country, which may be often seen in marl-pits, gravel-pits, or in hollow lanes. But they may in general be found above any moist or morassy plain or valley; the moisture of which shews, that springs exist in the strata on that side of the mountain.

A second observation for the purpose of detecting springs may be made on misty evenings; as those parts of the ground, where the

mist commences, are moister than those in their vicinity on the same level; and in consequence may generally, if they are not hollow basons, possess springs nearer the surface; for these moister parts of the ground, having evaporated more during the day, are become colder on their surfaces than the drier ground in their vicinity; and in misty evenings, which are at the same time calm, the stationary air over these moist parts of the ground is also more loaded with the evaporated moisture; and on both these accounts these moister situations are liable to shew a condensation of aerial vapour sooner than other places on the same level.

As mountains are colder in proportion to their height, which is explained in *Botanic Garden*, Vol. I. additional note 26, the evening mist sometimes commences sooner on them than in the valleys; but is seen earlier in these situations over the moister places, if they are on the same level with the drier ones, exactly as on the plains or valleys; and may therefore indicate the existence of springs, unless these moister places consist of hollow basons containing water, which if not attended to may in all situations deceive the observer.

Another observation for detecting springs may be made in rimy mornings; for as moist earth is a better conductor of heat than dry earth, the rime will sooner melt on those parts of the soil, which are kept moist by springs under it than on other parts; as the common heat of the earth, which is 48 in this country, will sooner be conducted upwards in moist places to dissolve the rime on the surface. On this account the rime is frequently seen on frosty mornings, when the heat of the air is not much above 32, to lie an hour longer on dry cakes of cow-dung, or on bridges, or planks of wood, than on the common moist ground; as the latter much better conducts the common heat of the earth to the incumbent rime, which is in contact with it.

But as the heat of the common springs in this country is 48, where they exist, the rime is sooner dissolved, than on the stagnant moisture

ture of bogs or morasses. And as the springs about Buxton and Matlock, and at Bath and Bristol, are so much warmer than common springs; it is highly probable, that where these waters approach the surface of the soil, they must much sooner dissolve the rime on frosty mornings; which may probably be observed in situations much higher than their present apparent sources; as they slide down between the interior strata of those hills, beneath the summit of which they are condensed from the steam of water boiling at great depths in the earth; which rises up through those perpendicular clefts of the rocks, which were formed at their original elevation, as explained in Botanic Garden, Vol. II. note on fucus; and in Pilkington's View of Derbyshire, V. I. p. 256.

In the winter months the rise of springs may be detected in moist ditches by the presence of aquatic plants, as of water-cress, water-parsnip, brook-lime; as in those ditches, which become dry in the summer, these plants do not exist; and when those ditches with springs in them are nearly dry, it may be discovered which way the current has formerly descended by the direction of the points of the leaves of the aquatic plants as certainly as by a level; an observation which I learnt from Mr. Brindley, the great canal-conductor of Staffordshire.

Finally, these arts of detecting the situation of springs may be advantageous to the attentive agricultor both for the purposes of draining those lands, which too much abound with water, and for the purpose of watering those, which are too dry, and which lie beneath the level of the springs, or to which the water may be raised by wind-mills or water-engines to be explained hereafter.

II. 1. In respect to draining those plains or morasses where no fall can be had, the water may in many situations be caught by cutting a long horizontal ditch into the adjoining mountain perpendicular to the inclined plane, which constitutes the side of the mountain, above the level of the morass, so as to intercept all the wall-springs; and

may

may then be conveyed away in wooden troughs or hollow bricks above the surface; and if some water still finds its way into the morafs, this lefs quantity may be conducted to one extremity of the ground in open drains or covered foughs, and raifed by an horizontal windmill and centrifugal pump, as described at the end of this Section; and thus the morafs may be converted into foil of the moft productive kind.

2. There may be other f Situations, as in the Peak of Derbyshire, where pools of water, or moraffes, are collected on the hollow fummits of hills; which have been the craters of volcanoes in the primeval ages of the world, as Elden-hole near Caftleton, which feems to have been the fhafte of fuch a volcano. In many of thefe bafons on the fummits of hills there ftill exift what are called “ Swallows,” or cavities; where the water finks into the earth, as it collects, to pafs to fome diftant valley, as Elden-hole above mentioned, and as in the channels of the rivers Hamps and Manifold, between Afhbourn and Leek. In others, as at the fummit of a fteep promontory called Axedge, near Buxton, and about Broke-houfe, are unfathomed moraffes, which are faid in fome places not to bear a fheep to pafs over them; and that on the more tenacious parts of them it is neceffary for the adventurer to ftep from tafsock to tafsock, or to carry a long pole horizontally in his hand, like thofe who fkaite upon fufpected ice, to prevent his finking over head, if he fhould chance to fink at all.

It is probable, that by finking a well, or boring a hole, where fuch moraffes or lakes now exift, into the obftructed fhafte of the ancient volcano, the water might be let off from thofe eminent moraffes at lefs expence, than by excavating a paffage for it fome miles in a country of marble.

3. It is poffible there may be f Situations in high countries of marble, or granite, or quartz, where the difficulty and expence of excavating the ground may be too great, as above; in which a ftyphon might be contrived for the purpofe of raifing the water from a mo-

rafs or lake, and conveying it away. Such an instrument might be constructed of bored Riga deals ; but as air is liable to collect in the summit of a syphon from the water, which passes through it, it would be necessary to fix at the summit an air-vessel with an air-pump at the top of it ; which might be moved by a very small horizontal windmill sail, to be described at the end of this Section, or occasionally by the hand of a labourer for a few minutes perhaps once or twice a day.

4. The draining of those large plains, which lie beneath the level of the sea, is a subject, which belongs to the public, rather than to the individual farmer ; and is practised near Linn on the river Cam. by locks to keep out the tide, and by windmills to lift or forward the otherwise stagnate water in the fen-dikes. These windmills have vertical sails of the common kind, which move a vertical water-wheel, by which the water is raised a foot or two ; but it is probable even this might be done better by the horizontal sail and centrifugal pump to be described at the end of this Section, as being a simpler machine, and requiring no attention to turn it to the wind.

It might be a noble work, worthy the attention of a government, that wished to increase the quantity of nutriment, and consequent population and happiness of the country, to employ proper engineers with a number of labourers to environ with ditches every morassy district of whatever extent, which lies beneath the level of the tides, as the fens of Lincolnshire and Cambridgeshire. These ditches should be cut at the feet of the adjacent rising grounds, or of eminences surrounded with fens, like islands in a lake, so as to intercept the wall-springs and land-floods, and convey the water thus collected above the level of the morafs into the ocean.

But this, I fear, is an effort not to be expected in the present times, when the enclosure of forests and large commons is prevented by the interest of individuals, or by the difficulty of procuring expensive acts of parliament for every minute district, instead of including them in a general

a general act, so meritoriously contended for by sir John Sinclair, then President of the Agricultural Society.

5. Where finally the draining of marshy grounds can not be effected at a responsible expence, some plants may perhaps be cultivated with profit to the cultivator ; as in some situations the *festuca fluitans*, floating fescue, *callitriche*, star-grass ; or in others the orchis for the purpose of making saloop by drying the peeled roots in an oven. This might be better worth notice, if the seed could be ripened in this climate for its easier propagation, which probably may be accomplished either by cutting away the new root, as is affirmed in the *Amœnitates Academicæ* ; or by planting them in a garden-pot so as to confine the roots in respect to space, which is said in the same work to ripen the seeds of *convallaria*, lily of the valley ; and lastly by cultivating a few on a hot-bed or in a green-house.

In other situations the *menyanthes*, bog-bean, would flourish abundantly, and might become a substitute for hops in the brewery, and be equally wholesome and palatable. It is indeed much to be lamented, that we have no grain similar to rice, that will grow in watery grounds in this cold climate, nor any esculent roots or foliage except the water-cress. There is reason to believe nevertheless, that the roots of *nymphæa*, water-lily, or of *butomus*, flowering-rush, may be esculent by simple boiling ; or that a wholesome starch might be obtained from them ; or lastly, that they might be fermentable into ardent spirit, like the roots of potatoes, or into vinegar.

The *nymphæa nelumbo* is much cultivated in China in their swampy grounds, and in their lakes. The seed is like an acorn, and of a taste more delicate than that of almonds. The roots are sliced and served with ice in summer at their tables ; and are preserved in salt and vinegar for the winter. Embassy to China by sir G. Staunton, Vol. III. p. 214, 8vo. ed. The *nymphæa alba* of our country produces a root of three or four inches in diameter. See Sect. XVII. 2. 3 ; and though the seed is very small, and perhaps does not perfectly

fectly ripen, I have observed it to be agreeable to the palate both in its recent state, and when dry.

If these should not succeed, other quick-growing plants might be cultivated for manures, as typha, cat's-tail, caltha, and others; which should be mowed twice a year, while they are young, and in consequence abound with saccharine and mucilaginous matter ready to pass into fermentation.

III. 1. The advantages resulting from occasionally covering lands with water have long been experienced in warmer countries, as in Egypt, Italy, and many parts of China; and have of late years been introduced into our own more northern climates. The great importance of much water to the progress of vegetation has already been spoken of in Section X. 3. And in the warm climates above mentioned, it is particularly useful in the cultivation of rice for the purpose perhaps of simply moistening the ground.

But the advantages of flooding meadow-lands in this country may be divided principally into three kinds, one of which consists in simply moistening them, which seems to be the principal use of watering lands in warm countries, where the water is derived to them almost every evening from reservoirs above them, or from water-wheels worked by asses, and which is sometimes done in the gardens of this country by watering pans and human labour.

The second and greater advantage of flooding lands in this climate consists in deriving much water over them from rivers or from strong springs, and by thus supplying them with the muddy sediment brought down by rivers, after sudden rains, or with the calcareous earth dissolved in many springs. All those springs, which pass through marl, or chalk, or other limestone, are replete with calcareous earth; which they hold in solution, as those about Derby and about Matlock, which earth they deposit on standing on the soil, or in slowly trickling over it. See Sect. X. 6. 2. And river

water in rainy seasons is loaded with diffused as well as with dissolved materials from the neighbouring country.

Both these therefore are of great service in flooding meadow-lands, and perhaps almost all other lands. But those springs, which pass only through siliceous sandstone, as those at Lichfield in Staffordshire, have no calcareous earth dissolved in them, as I have found by experiment; and the water of most rivers, when they are not swelled by rain, are also too pure for this purpose; as they have deposited already in their course the calcareous earth, which might abound in the springs, which feed them; as I have observed by experiments on the water of the Derwent at Derby, which though it runs for many miles about Matlock through a bed of limestone, yet when clear of mud from rains, it contains no calcareous earth, as it passes by Derby, though the springs in the vicinity are replete with it. Neither of these sources of water can therefore do much service for this second design of depositing limestone, or mud.

The third advantage of flooding lands in this climate is for the purpose of defending them from the cold of the winter or vernal months. For this advantage the water from strong springs, which are always at 48 degrees of Fahrenheit in this country, is preferable to river water, where it can be had in sufficient quantity; since the water of rivers is of the same degree of cold as the atmosphere, till the thermometer sinks to 32. But both of them, when they form a sheet of thin ice, as they cover a meadow, defend the roots of the grasses from severer degrees of cold; which are thus preserved, and those of some grasses are believed even to vegetate beneath the ice, as the rein-deer moss in Siberia vegetates beneath the snow in a degree of heat about 40, which is the medium between that of the under surface of the thawing snow, which is 32; and that of the common heat of the interior parts of the earth, which is 48; and thus the roots of grasses in this cold climate may be wonderfully forwarded; so

as

as almost to double the product of the year, if well managed and carefully attended to.

The method of forming the channels to convey the water consists in carrying the first or principal aqueduct along the highest part of the meadow, and deriving others on the summits of the lands; if the meadow has formerly been ploughed into ridges and furrows, these again are to be divaricated so as to pass into the furrows; all these branches of the stream are again to be collected from the furrows, and discharged at the lowest part of the surface.

Something similar to this must be managed on more level grounds, so as to conduct the water over the whole meadow, and also to carry it off, that it may not stagnate; but that a moving sheet of water about an inch in depth may continually flow over the whole for the purpose of depositing the materials dissolved or diffused in it. The construction and width of these channels, with many useful observations, are shewn in a pamphlet of Mr. T. Wright, on "the Art of Floating Land in Gloucestershire." Scatcherd. London.

2. Mr. Wright in the treatise above mentioned advises, that the aftermath of grass land should be eaten off bare by the beginning of November, and that the channels for conducting the water to and from the meadows should be then cleansed and repaired; and that the water should be suffered to flow over the meadow for three weeks; and that then the land ought to be exposed to the air for a few days; since some of the grasses, and those of the most nutritive kinds, he believes will not much longer exist under water. By this early preparation, he adds, that advantage is taken of the autumnal floods, which bring along with them a greater quantity of putrescent matter than those of winter.

In the months of December and January Mr. Wright adds, that the chief care of the floater consists in keeping the land sheltered by the water from the severity of frosty nights; but advises through the whole of these months every ten or fourteen days to expose the land

to the air by laying it as dry as possible for a few days; and always to discontinue the flooding, when the land is covered with a sheet of ice.

In the month of February greater attention is required; if the water be suffered to flow over the meadow for the space of many days without intermission, a white scum is generated, and the grafs is much injured. And he justly observes that, if you now take off the water, and expose the land in its wet state to a severe frosty night, a great part of the grafs will be cut off.

Mr. Wright adds, that in Gloucestershire two methods of avoiding these injuries are practised: one is to take off the water by day to prevent the production of the scum, and to turn it over again at night to guard against the frost. The other is to take off the water early in the morning; and, if the day be dry, to suffer it to remain off a few days and nights; for if the land experiences only one drying day, the frost at night will do little injury. But the former of these practices, where it can be easily done, he thinks preferable to the latter.

In the beginning of March the grafs on well-flooded meadows will generally be so forward, as to afford abundant pasturage, and the water should be taken off for about a week, that the land may become dry and firm; and the cattle should for the first week be allowed a little hay in the evening, if the weather be cold and rainy.

In the month of April the grafs may be eaten off quite short and close, but not later; since if you trespass but one week in the month of May, the crop of hay, which is to succeed, will be much impaired; and the grafs will become soft and woolly, and the hay have the appearance of lattermath hay, and be less valuable.

At the beginning of the month of May the water is again thrown over the meadows for a few days; which simply by moistening the land will in most seasons, Mr. Wright observes, ensure a crop of hay of one ton and a half on an acre in the course of six or seven weeks.

The

The water is sometimes again used, when the hay is carried off, but may render the lattermath, he thinks, unwholesome to sheep. But this is particularly serviceable, when the water is rendered turbid by suddens rains. Some have taken off two hay-crops in one year, but this Mr. Wright thinks is imprudent in this climate; which however I suppose might be accomplished, where the first growth is not eaten in April, and where much turbid river water or calcareous spring water can be used between them.

Mr. Wright further observes, that the hay on these flooded meadows is little inferior to upland hay, if it be cut at its proper age; but that some avaricious farmers have permitted it to remain uncut till it produces three tons on an acre, and that then it will become long and coarse, and little better than straw. But that when it is cut in June, and has been flooded well with muddy water in the winter, that it becomes little inferior to the best upland hay.

The hay, I should suppose, which is cut before the grafs is in full flower, while the saccharine juice still remains in part at the joints of the flower-stems, must contain the most nutritious matter; which is afterwards absorbed as the flower expands, and as the seed ripens, and forms the meal or starch of the seed-lobe, and is shed upon the ground, or consumed by birds, and the grafs-stems and their leaves become simply like the straw of ripened corn.

This will appear of more importance to any one, who attends to the difference of the pods or husks of peas, or of kidney-beans, during the early state of the enclosed seeds, and again after the seeds become ripe. The pod or capsule is at first sweet and mucilaginous, so as to supply an agreeable and nutritive food, the latter of which, and sometimes the former, are eaten at our tables; afterwards as the seeds, which are attached alternately to each side of the capsule, drink up by their vegetable life after impregnation the saccharine and mucilaginous matters there purposely deposited for them; the capsule itself becomes

becomes a mere fibrous membrane not better than the straw of ripe grains above mentioned.

It may be here repeated, that one great use in this country of flooding grafs-grounds in winter, and in early spring, so as to let a thin sheet of water perpetually flow slowly over them, is, that it will in frosty nights, when the cold is not much below the freezing point, produce a thin sheet of ice, and thus prevent the cold from affecting the roots of the grafs beneath it; which may thus be two or three weeks forwarder than on other lands; for ice is so bad a conductor of heat, that water is not readily frozen beneath it; and especially if it stands hollow, so as to enclose a stratum of air between itself and the water beneath.

This seems to have been attended to by the philosophers in the French army, when they passed over ice to subdue Holland; fearing least the ice should be too weak for the passage of their troops and artillery, they bored many holes through it every night; and then by pressure on its surface the water was made to rise through these holes, so as to stand an inch above the surface; which being thus exposed to the cold air of the night, became frozen before morning; and thus in a few nights thickened and strengthened the ice ten times more than would have been done naturally by the slower freezing beneath it.

3. To recapitulate the advantages of flooding, first, not only the common meadow grounds are enriched, but morassy ones are consolidated, by the mud brought over them from river water; or the calcareous sediment, and azotic or nitrogen air, from most spring waters, during those seasons when grafs does not naturally make much progress in its growth. 2. They are defended from frost by the flowing water, or by the ice, when it is frozen; and thus a much forwarder crop of grafs is produced, as may frequently be seen over pieces of ground naturally moist; which look green in the spring,
some

some weeks before that on drier land in their vicinity. 3. The ground is rendered more easily penetrable by the roots of grafs, both by its being kept softer, and also from its being feldomer frozen below the surface in the vernal months. 4. This early crop may be eaten off by cattle or sheep, and a new flooding for a short time will forward the growth of it so as to produce a good crop of hay. 5. After the hay is removed another flooding for a short time ensures a luxuriant growth of autumnal grafs, or aftermath.

The difficulty of getting moist lands free from rushes is said to be readily overcome by flooding them, and that especially after previously mowing them, as their spongy pith will then absorb so much water, as to cause them to putrify by its stagnation; or if this be done in autumn or spring, and a frost supervenes, the water in their pith by expanding, as it becomes ice, bursts and destroys their organic structure.

The following conclusion is copied from Parkinson's Experienced Farmer. "Upon the whole, artificial watering of meadows is a most profitable improvement; it robs no dunghill, but raises one for the benefit of other lands; for if a farmer can water ten acres of land, cut the grafs and use it either in stall or fold-feeding, he might keep perhaps forty beasts; and by working the manure made by them into a compost, and applying that compost to other lands, he might either have a great deal more hay for the winter, or feed more cattle in the summer." Vol. II. p. 68.

4. Two or three observations of importance should be here inserted. 1. That in flooding lands for a considerable time, the water should only trickle over them from the canal, which leads it along the more elevated parts, and not stand on it like a fish-pond; as in the latter case the grafs roots will perish in a few weeks in the early spring, to the great injury of the farmer, an example of which on several acres I once witnessed.

As soon as any materials thus begin to putrefy beneath the water,

a scum of white froth arises owing to the air set at liberty by putrefaction; which is supposed by some to injure the grass, whereas it is a consequence rather than a cause of injury, and shews, that the water has stagnated too long; and should either be immediately drawn off, or supplied by a running stream; but the former should probably be preferred: if the stems of grass are so tall as to rise above the running water, it is probable, that their death and putrefaction do not so soon occur.

Secondly. It is observed by gardeners, that in dry seasons, if you begin to water any kinds of plants, you must continue to repeat it; otherwise that they are sooner injured by dry weather, than those which have not been watered. This fact also I think I have observed, and it may depend on the circumstance of the roots of annual vegetables shooting themselves lower down in dry seasons in search of moisture; but if this be given them in the commencement of their growth, they then shoot their roots more horizontally, and are afterwards in consequence sooner destroyed by the subsequent dry weather.

Thirdly. Much cold water given suddenly to plants, which were nearly perishing with heat and dryness, will I believe sometimes injure or destroy them, as I saw occur this year, 1798, in June to some rows of garden beans; which after being flooded for one night withered, and in part died, on the following day, which was probably caused, not by the excess of water, as plants of this genus would seem to bear much moisture from an experiment of Lord Kaimes, who says in the Gentleman Farmer, that he planted a pea on some cotton-wool spread on water in a phial, and that it sprung up, and shot roots through the cotton-wool into the water, and produced large pods full of ripe seeds. The death of these beans was more probably occasioned by the torpor of the system induced by cold, as occurs to those who have injudiciously drank much cold water, or plunged into a cold bath, when they have been previously much weakened by the
unnecessary

unnecessary activity of the system occasioned by continued heat, or great exercise. See Sect. XIV. 1. 1.

Nor is there reason to suppose that to whatever extent this mode of cultivation of grafts could be carried in this country, that any injurious effects in respect to the health of the inhabitants could be produced; as this mode of flooding is not by stagnant water, as in rice grounds; which D. A. J. Cavanilles, who has lately published a work on the cultivation of rice in the kingdom of Valencia, believes to be injurious to the health of the inhabitants. *Magaz. Encyclop.* T. 3.

In these cold climates the vicinity of running streams may perhaps be rather salubrious than the contrary; as the air is cooled in hot weather, and warmed in cold weather, by its contact with their ever-changing surfaces, till they become frozen. I at this moment recollect many, who lived to an healthy old age in the valley of the Trent near the very edge of the water, whose names I could repeat. But stagnate waters, from which putrid exhalations arise, produce agues in cold countries, as in the fens of Lincolnshire; and putrid fevers in hot ones; from which our armies suffered so much at St. Lucia both in the present and the last war.

5. This practice of flooding is capable of being extended to a wonderful degree in this country, not only by using the natural falls of brooks and springs, and by occasionally damming them up to supply higher situations; and by effectually spreading the land-floods from accidental showers over the inferior lands to a great extent. And lastly, the water, which is now dammed up to supply the numerous mills, might be diffused in rills over a thousand meadows, or part of it be raised by pumps to higher grounds; and thus fertilize and enrich the country; while the grinding of corn, spinning of cotton, rolling iron bars, and other mechanic purposes, might be effected by wind-mills, or steam-engines, in almost every part of the island.

For this purpose likewise the new method of raising water by the vis inertię or acquired momentum of moving streams might be well

applied, which was formerly used by Mr. Whitehurst of Derby on a small scale at Oulton in Cheshire, as described with a plate of the machine, to which an air-vessel is ingeniously added, in the Philosophical Transactions for the year 1775, Vol. LXV. p. 277, and which is now adapted to variety of ingenious machinery by M. Boulton, Esq. of Soho near Birmingham; and is well explained with two prints in the Repertory of Arts and Manufactures, No. LI.

6. The following water machine, which is on the principle of Hiero's fountain, is designed to raise part of the water of a spring, or small brook, where some feet of fall may be acquired, to a greater height for the purpose of watering higher levels of ground; and the horizontal windmill with centrifugal pump is designed for the same purpose, where no fall can be acquired. We shall then perhaps have satiated some of our readers with this subject of watering lands, and may conclude with the shepherds in Virgil's Eclogue,

Claudite jam rivos, Pueri, sat prata biberunt.

PLATE V.

PLATE V.

Represents the strata of a hill. *ab* is the upper stratum, suppose of marle; *cd* is the second stratum, suppose of sand; *ef* represents the accumulated earth in the valley. It is designed to shew, that in boring holes through the upper stratum to find that beneath it, they should be formed perpendicular to the side of the mountain, and not perpendicular to the horizon, as is the common practice, as by those means the hole *yy* is much shorter than the hole *xx*. As explained in Sect. XI. 1. 5.

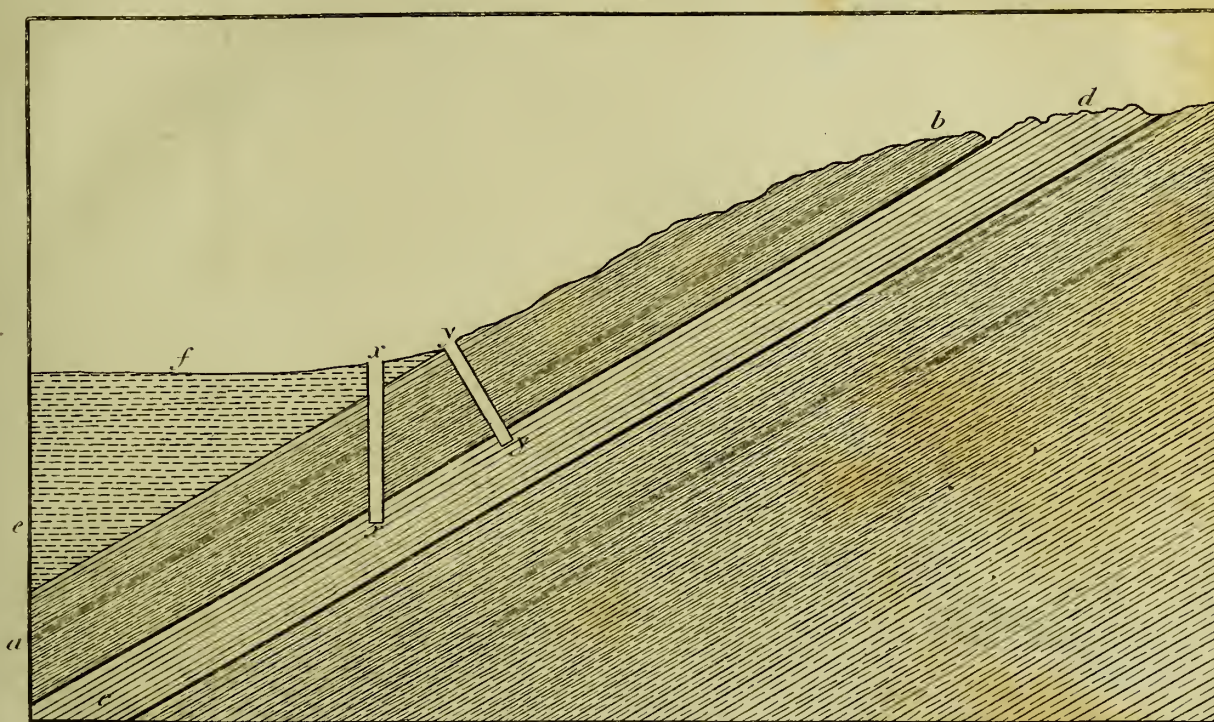


PLATE VI.

PLATE VI.

Is a section of a machine similar to Hiero's fountain, but designed to raise water to a great perpendicular height, where there is the convenience of a small fall.

a b the stream of water, *b c c* the height of the fall of it, suppose ten feet, *d e* two vessels of lead or iron containing, suppose, four gallons each, *f g b i k l* are vessels of lead containing, suppose, two quarts each, *o p* two cocks, each of which passes through two pipes opening one and closing the other, *q r* a water balance moving on its centre *s* and turning the two cocks *o* and *p*, alternately, *t u* and *w x* two air-pipes of lead one quarter or half an inch diameter within, *y z, y z, y z*, water-pipes one inch diameter.

The pipe *b c c* is always full from the stream *a b*, the small cisterns *g i l*, and the large one *d*, are supposed to have been previously full of water, then admit water by turning the cock *o* through the pipe *c c* into the large cistern *e*. This water will press the air, which was in this cistern *e* up the air-pipe *w x*, and will force the water from the small cisterns *g i l* into the cisterns *b k* and great *C*. At the same time by opening *B*, the water and condensed air, which previously existed in the large cistern *d*, and the small ones *f b k*, is discharged at *B*. After a time the water balance *q r s* closes the cocks now open, and opens their-antagonists, and the cisterns *f b k* are emptied in their turn by the force of the condensed air from the cistern *d*, as the water enters into it from the pipe *b c*.

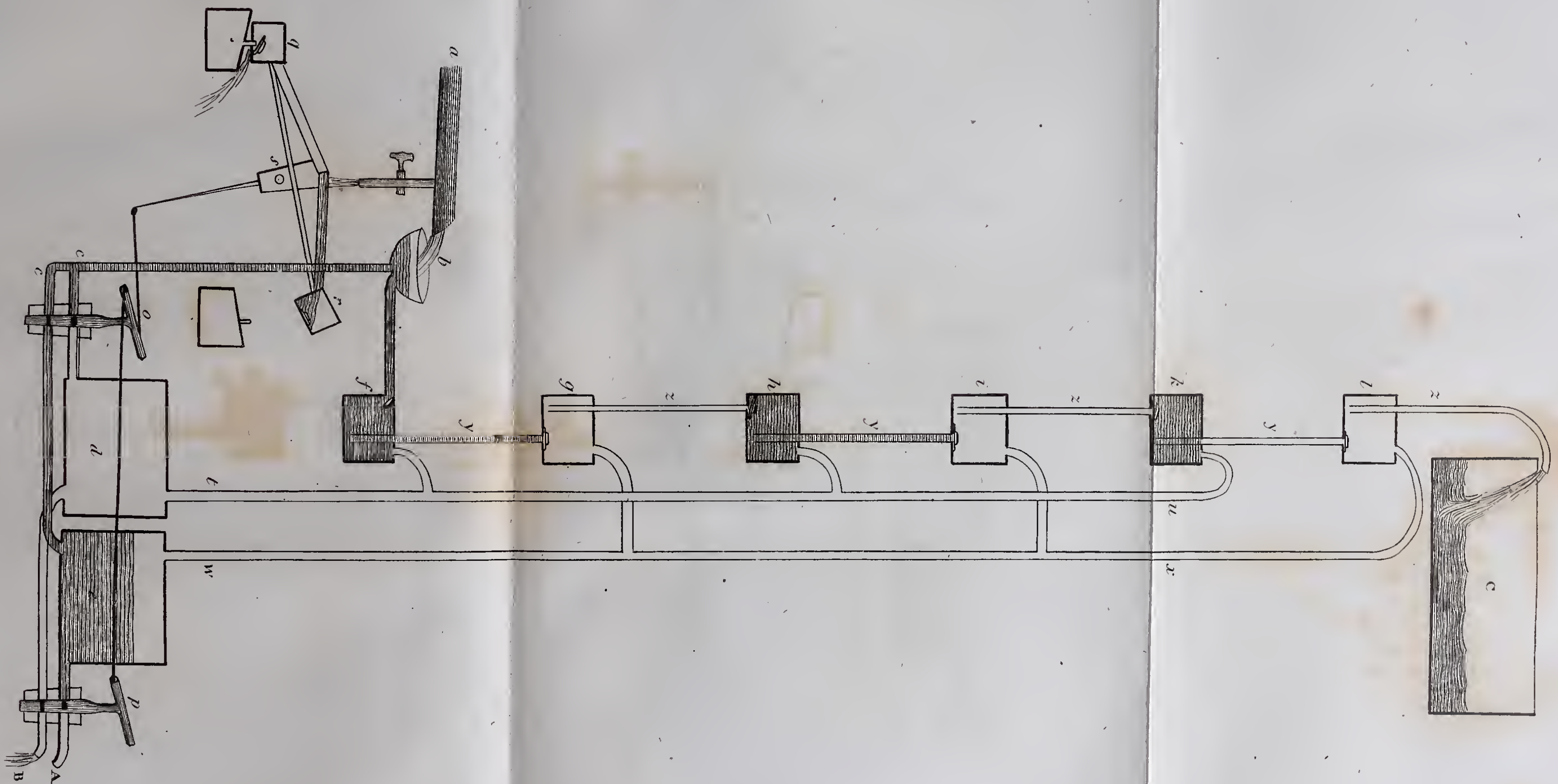


PLATE VII.

PLATE VII.

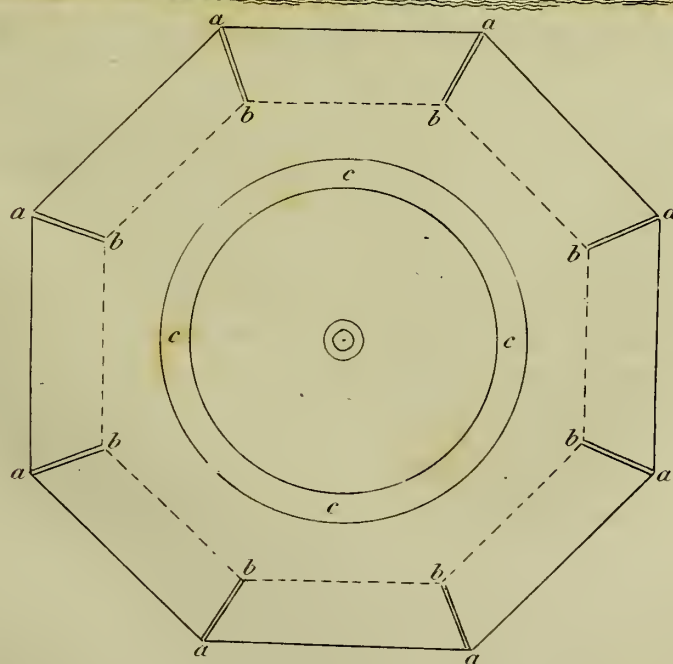
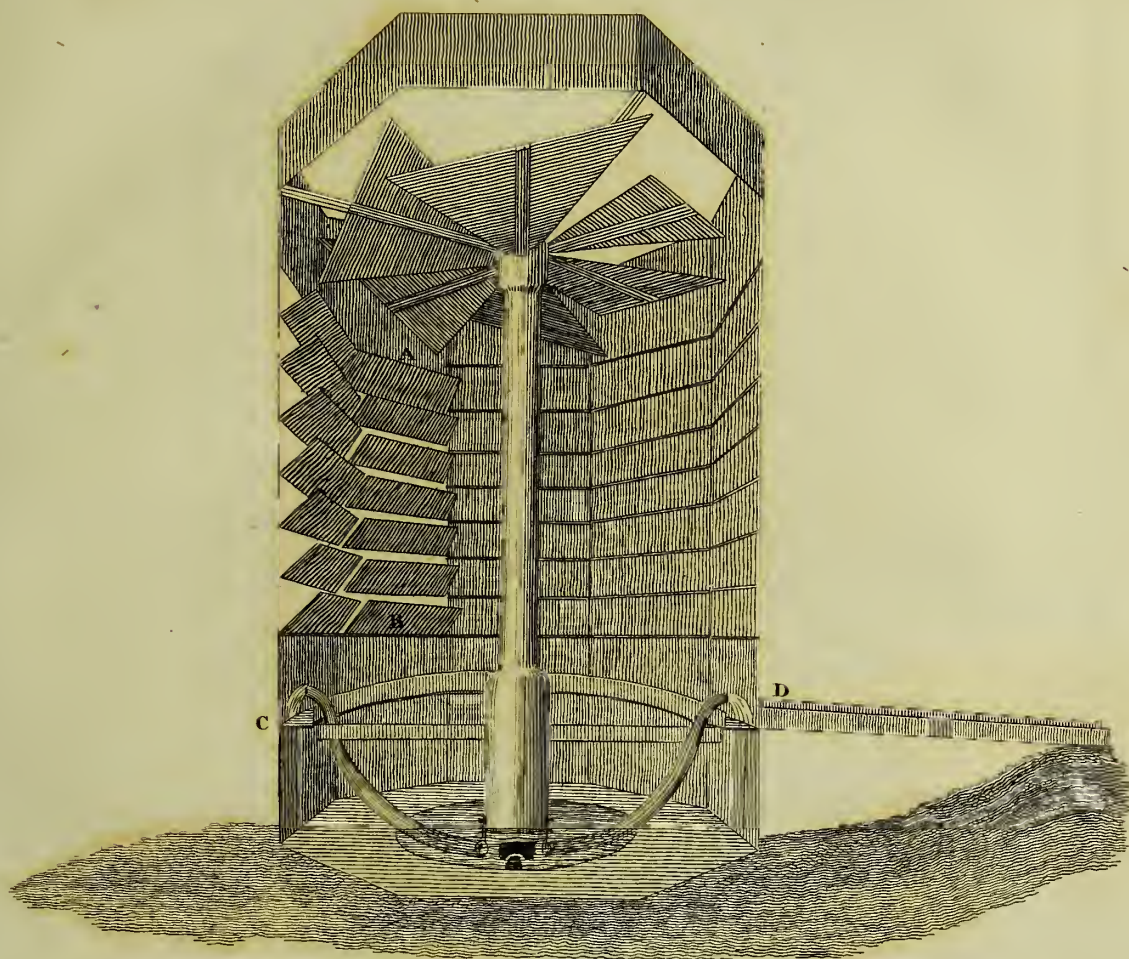
Is a section of a machine for raising water a few feet high by the power of the wind for the purpose of draining morasses, or of watering lands on a higher level.

It consists of a windmill sail placed horizontally like that of a smoak-jack, surrounded by an octagon tower; the diverging rays of this tower, *a b, a b*, may consist of two-inch deals only, if on a small scale, or of brick-work if on a larger one. These upright pillars are connected together by oblique horizontal boards as shewn at *A B*, by which boards placed horizontally from pillar to pillar, in respect to their length, but at an angle of about 45 degrees in respect to their breadth, so as to form a complete octagon including the horizontal windmill sail near the top of it; the wind as it strikes against any of them, from whatever quarter it comes, is bent upwards and then strikes against the horizontal wind-sail. These horizontal boards, which form the sides of the octagon, may either be fixed in their situations, or be made to turn upon an axis a little below their centres of gravity, so as to close themselves on that side of the octagon tower most distant from the wind.

It may be supposed that the wind thus reflected would lose considerably of its power before it strikes on the wind-sail, but on fixing a model of such a machine on the arm of a long whirling lever, with proper machinery to count the revolution of the wind-sail, when thus included in a tower and moving horizontally; and then when moved vertically as it was whirled on the arm of the lever with the same velocity, it was found on many trials by Mr. Edgeworth of Edgeworth Town in Ireland, and by myself, that the wind by being thus reverted upwards by a fixed planed board did not seem to lose any of its power. And as the height of the tower may be made twice as great as the diameter of the sail, there is reason to conclude that the power of this horizontal wind-sail may be considerably greater, than if the same sail was placed nearly vertically opposed to the wind in the usual manner.

At the bottom of the shaft of the wind-sail is placed a centrifugal pump with two arms at *C D*, which has been described in mechanical authors. It consists simply of an upright bored trunk, or cylinder of lead, with two opposite arms with an adapted valve at the bottom to prevent the return of the water, and a valve at the extremity of each arm to prevent any ingress of air above the current of the water as it flows out.

c c c c is a circular trough to receive the streams of water from *C* and *D*, to convey them where required.





S E C T. XII.

AERATION AND PULVERIZATION OF THE SOIL.

- I. *Soils contain inflammable matters and water. Air consists of oxygen, nitrogen, and heat. Produces carbonic, nitrous, and phosphoric acids, and volatile alkali with water when buried in the soil. Heat and light given out from the union of carbon and oxygen in a letter-wafer. Sow and set soon after the plough or spade. 2. Penetrability of the soil increased, and mixture of its ingredients. Retains the rains. Enlarges the surface. 3. Uses of fallowing. Turnips said not to impoverish the soil, why. 4. Fallowing injurious to rich lands, why. 5. The great advantages of Tull's drill husbandry. Prefers horse-hoeing to hand-hoeing. An improved drill machine. 6. Advantages of transplanting wheat. 7. Of barrowing wheat in spring. 8. Rolling wheat in spring.*

As almost all soils not only contain carbon, and other inflammable materials; which are capable of uniting with oxygen, and thus producing the carbonic and other acids; but also contain water, which by its decomposition, when in contact with confined air, produces ammonia or volatile alkali by the union of its hydrogen with azote; and nitre by the union of its abundant oxygen with another part of the abundant azote or nitrogen of the atmospheric air; there is reason to conclude, that the great use of turning over the soil with the plough or spade depends principally in the production of these effects by the confinement of both the oxygen and the azote or nitrogen of the air in the interstices of the soil; and on this account we have entitled this section the aeration of the soil rather than the oxygenation

of it, as the latter belongs to the respiration rather than to the nutrition of vegetables.

When atmospheric air is imprisoned in the cavities of the soil by turning over its surface, which must be in greater quantity, when the soil is reduced into the very small fragments, which has been called pulverization; and when it is the least pressed down by animals trampling on it, it more readily unites, I believe, with the materials above mentioned than in its free state; which is probably effected by double or triple chemical affinities.

For this atmospheric air consists of oxygen, azote, and the fluid matter of heat; now if the heat, which occasions the oxygen and azote of the atmosphere to exist uncombined in the form of gasses, be attracted from them by any other material, as they are confined in the cavities of the soil, they may by their nearer approach to each other combine into nitrous acid; or the oxygen may in its fluid state, not in its aerial one, more readily unite with carbon; and form a fluid, not an aerial, carbonic acid; which we believe to be of so much consequence in the growth of plants, as shewn in Sect. X.4.

Add to this, that if any putrefactive process be proceeding, where atmospheric air is thus imprisoned in the cavities of the soil, and by the loss of its heat is converted from a gas to a fluid; that the azote may unite with the hydrogen of the decomposing water, or contribute to decompose it; and thus to form volatile alkali, which like the nitrous acid, may either during the process of its formation, or after it is formed, be of effectual service to vegetation, at the same time the oxygen given out from the decomposing water may contribute like that of the atmosphere to produce carbonic, nitrous, or phosphoric acids; and thus to render carbon, phosphorus, and the basis of nitre, capable of being absorbed by vegetable lacteals.

Where atmospheric air is confined along with water, I well remember from experiments I made long ago, by inverting a bottle filled with air in a jar of water, that the bulk of the air was in some days

days so much diminished as to occupy only half the bottle, which probably occurs from the decomposition of both the water and air ; and the production of ammonia and nitrous acid, both which are believed to be so serviceable to vegetation, as mentioned in Sect. X.

2. 9.

That the heat of the atmospheric air is given out, when oxygen unites with carbon, is shewn by the heat of hot-beds ; and of fermenting saccharine and mucilaginous fluids, as in the production of ardent spirit ; and may be beautifully seen in the combination of oxygen with carbon in the burning of one of those common letter-wafers, which consist of the mucilage of flour, and red lead or minium ; not one of those, which are called Irish wafers, and which are coloured with vermilion. If one of these minium wafers be made to blaze in the flame of a candle, the oxygen contained in the minium unites with the carbon of the flour, and gives out a very luminous spark, and consequent great heat, and at the same instant a small globule of melted lead drops down, and may be agreeably seen, if received on a sheet of white paper held under it. It is also probable, that heat is emitted during the production of nitrous and of phosphoric acids.

From these observations it appears, that seeds should be sown, and roots planted, soon after the soil is turned over ; while the production of the carbonic, nitrous, and phosphoric acids, and of volatile alkali, and perhaps many other processes, are proceeding, rather than after they are completed ; and also while the fluid element of heat is passing from its combined state, and permeating the soil, which in this cold climate in the vernal months must be highly conducive to vegetation.

2. By thus turning over the soil with the plough or spade the penetrability of it by the roots of plants is also much facilitated ; and for this purpose, as well as for the admixture of atmospheric air, it can scarcely be reduced into too fine molecules, or a kind of wet powder ;

der ; for the moisture of soil is as necessary for its being permeated by the young roots of plants, as its small cohesion, as mentioned in Sect. X. 3. 6.

Secondly, a more intimate mixture of the various ingredients, which most soils possess, as carbon, calcareous, argillaceous, siliceous, and magnesian earths, with various metallic oxydes, as those of iron, and sometimes of manganese, and calamy, all which by frequent turning over the soil with the plough or spade, become mixed so as to act on each other or on the roots of vegetables in every minute part of the soil.

And thirdly, the vernal rains are retained by their sinking more readily into the pores and cells of land recently turned over, and which still possesses an uneven surface. Besides a greater surface of it being continually exposed to the passing air, and to the heavier impurities, which it perpetually contains, as carbonic acid, foot, odours of many kinds.

3. A recapitulation of these circumstances leads us to the knowledge of the use of fallowing lands, by repeatedly turning them over much carbonic acid is produced in its fluid state ; and perhaps some of the nitrous and phosphoric acids ; these may remain united with the vegetable recrements, or with volatile alkali, or with calcareous earth. 2. The parts of the soil may become better mixed together, and thus either chemically affect each other to their mutual melioration ; or they may more uniformly supply nutriment to the roots, which penetrate it. 3. The soil may become broken into a moist powder, and may thus be more easily permeated, and supply a greater surface of its cavities for the vegetable absorbents to apply themselves to. 4. Unprofitable plants, or weeds, not being permitted to grow on it, or their being perpetually ploughed under the soil in their early growth, much vegetable nutriment will be reserved by not being expended ; or it will be increased by the saccharine and mucilaginous matter of the young plants, which are thus buried in it.

It

It should be added, that some plants are said not to impoverish the ground, on which they have grown during their herbaceous state, before the seed-stems have arisen; as turnips, when drawn up and carried away to feed cattle or sheep on other grounds. This has been ascribed by some authors to the soil having been shaded by their thick foliage, and thus not having suffered so much by evaporation. Some have ascribed this supposed melioration of the soil to its having been screened or overshadowed by the thicker foliage of such crops; and that as the putrefactive process of vegetable recrements proceeds best in damp and confined air, as wood decays soonest in cellars, they suppose the soil may thus become improved. But Mr. Tull seems either to doubt the fact, or to attribute it to the ground, where such plants are cultivated, being usually once or twice hoed; and thus in effect to have been followed by the repeated aeration and pulverization of the soil, and the destruction of innumerable weeds.

If nevertheless the fact be true, not only all the circumstances above mentioned may contribute to produce it, but also, as it appears by the experiments of Priestley and Ingenhouse, that though the perspirable matter of vegetable leaves gives out oxygen in the sunshine, yet that it gives out carbonic acid in the shade; which even in its aerial or gaseous form is much heavier than common air, and will therefore subside on the earth in the shade of this perspiring foliage, and contribute to enrich the soil by the hourly addition of carbon.

4. Nevertheless where the soil is already replete with manures, and these processes productive of carbonic, nitrous, and phosphoric acids, and of volatile alkali, are going on in proper abundance; such soils must be injured by being too frequently turned over in summer fallowing; and thus by exposing too great a surface, and that too frequently, to the air, the sunshine, and the rain; by which much of the fluid carbonic acid will be converted into aerial carbonic acid, and escape, as well as the phosphorus and the ingredients in their state previous to the production of nitrous acid, and of the volatile alkali. On

this account in the manufacture of nitre in France, Spain, and Prussia, it is directed to cover the compost of soil and animal recrements with a shed to prevent too great exhalation and ablution. Hence though a summer fallow may be of advantage to a poor soil, which has nothing to lose; it must be disadvantageous to a rich one, which has nothing to gain.

Lord Dundonald in his work on the Connection of Agriculture and Chemistry ingeniously supposes, that soils become injured, when much exposed to the air by fallowing, from the carbon or other inflammable matters uniting with oxygen; and that then being again combined with other materials, they become insoluble, producing limestone, calcareous nitre, and phosphat of lime. But there is another injury to soil by frequent fallowing, which I suspect to be more extensive, from the escape of carbonic acid, or of nitrous acid, or of ammonia, into the atmosphere in the form of gas, as above mentioned; or their being washed away by rains.

5. Hence the great advantages of Mr. Tull's ingenious discovery of the drill husbandry are easily understood, 1. By sowing the wheat in rows, scattered by a drill-plough at regular distances, and buried at a regular depth, the grain is neither crowded, nor too thinly dispersed. 2. Nor are the roots buried either too deep in the soil, or too shallow. 3. By turning the soil first from the rows in the spring for a week or two, and then turning it up against the rows, the soil becomes newly aerated with all the good effects in consequence. 4. It becomes more penetrable by the superficial roots of the corn. 5. By raising it to the second joint of the corn-stems, four or six new roots with new stems will shoot out, generated by the caudex of the second leaf of the corn-stem; which is now within the soil, or in contact with it, as explained in Sect. IX. 3. 1. and 7. XVI. 2. 2.

Thus Mr. Tull's method of heaping soil against wheat-plants up to the second joint answers in some degree the same purpose, as transplanting the roots, and setting them deeper in the soil with
much

much less expence of labour. But for the more perfect pulverization of the soil, and the more complete aeration of it, he insists much on the preference of horse-hoeing to hand-hoeing; as the former passes deeper into the soil, and thus exposes a greater quantity of it to the air; and especially of that part of it, which before lay too much beneath the surface to be previously much affected by the incumbent atmosphere. But the great objection to the use of the horse-hoe is, that the alternate rows of corn must be placed at too great a distance, as will be again spoken of in Sect. XVI. 2. 2.

To the many advantages of the drill husbandry above recited Mr. Tull adds, that “where the spring-turnips are used too late in the year, there is not time to bring the land into tilth for barley, and there is a loss of the barley crop in consequence; which he says is entirely remedied by the drilling method; for by that the land may be almost as well tilled before the turnips are eaten or taken off, as it can afterwards.” Husbandry, Chap. VIII. p. 89.

So many great advantages seem to accrue from Mr. Tull's method of drill-sowing and horse-hoeing, that a curious question offers itself, Why it has not been more generally adopted? First, I suppose, because it is difficult to teach any thing new to adult ignorance, so that the master must for some time attend the process with his own eye. Secondly, I believe the axle-tree of Mr. Tull's sowing machine did not accurately emit the proper quantity of seed from the hopper, and was liable to bruise and destroy some of it in its passage. And thirdly, that the improved drill machine of Mr. Cook's patent is too expensive for the purchase of small farmers, who fear that it may not answer the expected advantages.

I have therefore given a print at the end of this work of a machine constructed on a cheaper plan, which is simply an improvement of that described in Mr. Tull's book, by enlarging that part of the axle-tree which delivers the grain, into a cylinder of some inches diameter

with excavations in the rim ; which rim rises above the surface of the corn in the feed-box, and lets drop again into the feed-box, whatever grains fill the holes above the level of the rim, as that side of the cylinder ascends. Whence the quantity delivered is uniform, and no grains are in the way to be bruised or injured, as explained at large along with the print ; and the whole machine is simple, and of small expence.

6. The most effectual method of obtaining the great combined advantages of aeration and pulverization of the soil is by transplanting the roots of wheat, and parting them, as already spoken of in Sect. IX.

3. 7. By taking up the roots and replanting them in soil lately turned over, and consequently exposed to the air, which is now confined in its interstices, all the advantages already mentioned are effectually received, from the new made fluid, carbonic, nitrous, and phosphoric acids, and from the ammonia, and other unnamed combinations. Secondly, all the advantages arising from the easy penetrability of the loose soil by the root-fibres, which are believed by Mr. Tull to put out more radicles with absorbent mouths at every part, where they are dissevered, like a brush or pencil of hairs. Thirdly, by parting the root-scions from each other they acquire greater space of air for their respiring leaves, and of soil for their absorbent roots. Whereas when too many stems arise from one root, or many seeds are sown near together, a tussock is produced in a conical form rising highest in the center ; which seems to be occasioned by the contest of the stems for air and light ; their roots also must descend lower in their contest for moisture, and for other advantages of the soil ; whence many of these crowded stems become barren, producing no ears, or ill-corned ones.

Another benefit from transplanting corn is owing to the quicker tendency to fructification, and consequent sooner ripening of the grain. Thus transplanted garden beans and transplanted brocoli flower sooner, and I suppose produce less stems or straw, as mentioned

tioned in Sect. XVI. 1. 2. I am also well informed by the Rev. Mr. Pole of Radborne, that the roots of those turnips, which were drawn out of the ground and transplanted, became considerably larger than those, which were only hoed in the common manner; which I suppose to have been owing to many of the extremities of the roots having been torn off in drawing them out of the ground; and that thence the tendency to shoot up the new central stem is delayed, and the reservoir of nourishment accumulated in the tuberous root is thus increased in quantity, as several of these turnips weighed ten and eleven pounds; and hence probably the transplanting turnips by means of a cylindrical spade described in Vol. IV. of the Bath Society, which tears the roots less, might not have been so advantageous. Something similar occurs in transplanting fruit-trees. See Sect. XV. 2. 4.

But the great advantage of transplanting wheat above the drill-husbandry consists in being able at the same time to divide the root-scions from each other; and thus not only to prevent their crowding each other, but also wonderfully to increase the product from a single grain, with many other advantages mentioned by Mr. Bogle in the works of the Bath Society, Vol. III. p. 494.

Another great advantage of transplanting wheat consists in this, that it may be sowed in a garden, one acre of which will produce sets for one hundred acres, if they be divided and planted at nine inches distance from each other; and as they are not to be transplanted till the spring, wheat may be thus cultivated in moister situations than would otherwise be friendly to its growth.

And that a clean crop may be certainly thus procured; because if the land be ploughed immediately before the plants are set out, the corn will spring much quicker from the plants, than the weeds from their seeds; and the corn will thence bear down the growth of the weeds.

For many other particulars the reader is referred to the ingenious paper of Mr. Bogle above mentioned, who thinks the transplanting

might be done by boys and girls at a small expence; I shall only add, that rape-feed, which is generally sown in August, and not reaped till the August following, might be profitably transplanted, as well as peas and beans. And lastly, that it is probable, that some means of making the holes to receive the plants might be much expedited by a broad wheel to be drawn by a man or horse with prominent pegs on its periphery two inches tall, and nine inches asunder.

7. Another means of aeration and of pulverization has been used in respect to wheat crops by many with advantage, and that is by drawing a lightish harrow over a wheat-crop in the spring, which, where a crop is thin, is particularly recommended; and may also be of service where it is too thick.

The harrow by breaking the clods, and by turning up the soil against the stems of many plants, earths them deeper as in hoeing; and thus by burying the second joint occasions it to tiller, or shoot out new root-scions; at the same time the earth is exposed to the air, and many weeds are rooted up and covered, and some roots of the corn.

The drawing a sharp harrow over a field of wheat in the spring must cut or tear many of the roots of those stems, which it comes near, which according to Mr. Tull's theory would shoot out many new radicles, or pencils of fine roots, and thus acquire more nourishment. But I suspect that tearing of many of the root-fibres prevents the too luxuriant growth of the stem and leaves, and thence sooner produces the fructification, as in transplanting. At the same time the earth being loosened becomes more penetrable to the remaining roots, as well as more nutritive from its aeration.

Others have even ploughed a field at this season with good effect, as Mr. Bogle asserts; but both of them appear to be only inferior kinds of drill husbandry; and the former may so far be of considerable utility.

8. Another method of aerating and pulverizing the soil of a wheat field in spring is by rolling it, which may be done before or after the

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use of the harrow, or without it. As the surface of a wheat field is generally left rough with clods or eminences, the pressure of a heavyish roller will not only pulverize these, and thus expose their interior surface to the air, and raise the soil round the wheat-stems above the second joint, and thus induce them to shoot out new root-scions, or tiller ; but will also press down the wheat roots into the soil, and thus also promote the growth of new stems, as mentioned in Sect. XVI. 2. 5. if it be performed, when the ground is neither too wet nor too dry for such an operation.

S E C T XIII.

OF LIGHT, HEAT, ELECTRICITY.

- I. 1. **LIGHT** and heat are different fluids. *Light does not heat transparent bodies. A glass fire-screen, combines with opaque bodies, and heat is detrued.* 2. **Light** combines with solid oxygen, and with heat converts it into gas. *Perspiration of plants is decomposed by light. The hydrogen retained gives the green colour. Water hyper-oxygenated. Oxygenated marine acid. Colourless nitrous acid. A branch immersed in carbonic acid and water.* 3. **Etiolation** of vegetables. *Bleaching owing to oxygen. Colour of plants to hydrogen, and the yellow tan of the skin. Pure air from dew. Perspiration of plants oxygenated. Light tans living bodies, and bleaches dead ones, both vegetable and animal.* 4. **Use of light** in vegetable respiration. *Plants do not respire in the night. Truffles and fungi live without light.* 5. **Spring water** frequently oxygenated. *Air liberated by points.* 6. **Plants** require oxygen. *Fallacy of contrary experiments.* II. 1. **HEAT** universal. *Counteracts gravitation. Is the cause of fluidity, and of aeriform state. Particles of matter do not touch. Heat becomes combined. Is set at liberty in production of acids. In freezing water.* 2. **Frost** destroys fluidity. *Ice expands. Separates compound fluids from each other, and bursts the vessels of plants. Not of evergreens. Rime frosts and black frosts. Low situations not proper for gardens. Use of coping stones on fruit-walls. Rows of young peas from S. E. to S. W. Bend fig-trees on the ground. Frost erroneously believed to meliorate the soil, and to be wholesome. Clay rendered denser by frost. Snow protects plants. Animals covered with snow are not wet or starved. Lichen rangiferinus* 3. **Cold** destroys vegetable irritability. *Heat is a stimulus. Acquired habits of plants.* 4. **Cold** produced by evaporation. *Plants not to be watered in the sunshine.* III. 1. **ELECTRICITY** consists of two fluids. *Forwards the growth of plants whether positive or negative. Lightning destroys them.* 2. *It assists the decomposition of water in vegetables.* 3. **Clouds**

are generally electrified plus. Experiment on vapour. Rain from hydrogen and oxygen. Thunder showers. 4. Electric points to collect dew, and promote vegetation. Electric clock.

I. I. PHILOSOPHERS are not yet agreed, whether light and heat be the same fluid under different modifications, or two different fluids, which exist frequently together. The latter opinion seems to be more probable from the circumstances related below, and also from the analogy of other aqueous, aerial, or ethereal fluids, which appear to consist of two other fluids combined or diffused with each other. Thus water consists of oxygen and hydrogen combined together. Atmospheric air of oxygen and nitrogen diffused together. Electricity probably consists of two fluids, which may be termed vitreous and resinous electricity. Magnetism also probably consists of two fluids, which constitute northern and southern polarity. The power of attraction seems to consist of gravitation and of chemical affinity. And lastly, the element of fire consists I suppose of light and heat.

The dissimilarity of light and heat is evinced by this simple circumstance; that as light gives no heat to transparent bodies, which the emanations from a fire do, there is reason to believe them to be different fluids. Thus when smoke is blown near the focus of a large burning glass, it does not ascend; which shews, that the air is not heated and rarified by it; though it would burn or vitrify in an instant any opaque body, which might be opposed to it; but the emanations of heat from a fire soon rarify and warm the air in its vicinity, causing it to ascend, as may be seen by a spiral card-vann placed over a chimney-piece, and which is agreeably seen in the use of the new glass fire-screens of Parisian invention, which placed before a parlour fire permit the rays of light to pass, but intercept the emanations of fluid heat.

Whence it would seem, that light does not itself communicate heat to opaque bodies, when it falls on them; but combines with them,
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and by that union heat is detruded or given out ; which heat may produce inflammation of the material, if it be of an inflammable nature, by uniting it with the oxygen of the atmosphere ; and thus producing an eduction of more heat from the oxygen, and greater inflammation of the burning body.

2. Another essential difference between light and heat consists in the particular attraction of the former to oxygen ; inasmuch that by their union the combined or solid oxygen becomes changed into an aerial, or gaseous state ; as constantly occurs, when the sun shines on the hyper-oxygenated water, which is perspired or exhaled from plants, as mentioned in *Botanic Garden*, Vol. I. Cant. IV. l. 25. But as an addition of heat seems necessary to the conversion of a solid or fluid body into an aerial or gaseous one, I suppose the sun's light at the same time by combining also with the water sets at liberty some latent heat from it, which gives wings to the oxygen.

The water perspired by plants, when exposed to the sunshine, is believed to be decomposed, as it escapes from the fine extremities of the exhalent or perspirative vessels of plants ; and that the hydrogen is reabsorbed by the mouths of those vessels, as explained in *Botanic Garden*, Vol. I. note 34. That this happens to a certain degree is evinced by etiolated or blanched vegetable leaves becoming green, when exposed to the sunshine in a few days ; which is, I believe, produced by their retaining the hydrogen of the water they perspire, as it is decomposed by the sun's light.

But it is also probable, that the perspired fluid of plants is previously hyper-oxygenated in the vegetable circulation. First, because there is never perceived any smell of hydrogen to attend this process of liberating oxygen by the sun's light. And secondly, because the following productions of oxygen gas by the sun's light are similar phenomena ; though I suppose the points or hairs on vegetable leaves may contribute to the escape of the oxygen, as explained in *Botanic Garden*, Vol. I. note 10.

Sir Benj. Thompson, now Count Rumford, in a paper published in *Philos. Transact.* Vol. LXXVII. put thirty grains of raw silk previously washed into some spring water, and exposing it some hours to the sunshine obtained from it very pure vital air, or oxygen gas. In that experiment the spring water seems to have been in a state of hyper-oxygenation, and the points or fine edges of the raw silk to have assisted its liberation from the water in the sunshine, as explained in *Botanic Garden*, Vol. II. note on fucus. 2. The hyper-oxygenated marine acid is known very hastily to part with its superabundant oxygen in the sunshine. 3. Mr. Scheele inverted a glass vessel filled with colourless nitrous acid into another glass-vessel containing the same acid; and on exposing them to the sun's light, the inverted glass became partly filled with pure air, and the acid at the same time became coloured. *Crell's Annal.* 1786.

As water contains 85 hundredth parts of oxygen to 15 of hydrogen, it may become much oxygenated occasionally by a small loss of hydrogen in the vegetable system; or by the carbonic acid being decomposed in plants by the secretion of carbon, which constitutes so great a part of them; and that on both of these accounts they may yield oxygen gas, when exposed to the sun's light, as appears from the following experiment related from Von Uslar by G. Schmeisser. *Observat. on Plants.* Creech, Edinburgh, p. 92.

If two branches of a plant are immersed, one in common water, and the other in water impregnated with carbonic acid, we then find, that the branch immersed in the latter yields a much greater quantity of oxygenous gas in the sunshine than the other. The difference in some experiments has been found in the proportion of 264 to 1. But the proportions vary when different plants are subjected to trial. Thus the carbonic acid, with which the water is impregnated, is decomposed by the branch, the carbon apparently enters into the constitution of the plant, while the oxygen is set at liberty, and escapes

in the form of gas in the sunshine ; but not in the night, as then the carbon is perspired along with it.

3. A third circumstance, in which the effects of light differ essentially from those of heat, appears in the blanching or etiolation of vegetables ; under whatever temperature of heat a plant is kept, it becomes white, if the light be excluded from it, and is so far diseased, as mentioned in Sect. XIV. 2. 4. Whence all vegetables turn towards the window, if confined in a room, and in dense woods grow taller, than in open grounds, for the purpose of acquiring access to this necessary fluid. On this subject many experiments are related by M. Senebier on vegetables confined in a dark cavern.

From the experiment last related of the nitrous acid becoming coloured, when the superabundant oxygen was volatilized by the sun's light, or attracted from it ; and from the experiments of bleaching cotton by the hyper-oxygenated marine acid, where the union of oxygen with the colouring matter seems to destroy the latter by forming a new acid, which is colourless, it appears, that the absence of oxygen occasions the colour of vegetable bodies, probably by the accumulation of hydrogen ; and that on this account, when they are secluded from the light, they become white, or blanched, or etiolated, by their not being in a situation to part with so much oxygen, as when they are exposed to the light.

Hence plants growing in the shade are white, and become green by being exposed to the sun's light ; for their natural colour being blue, the addition of hydrogen adds yellow to this blue, and *tans* them green.

I suppose a similar circumstance takes place in animal bodies ; their perspirable matter is probably hyper-oxygenated ; and, as it escapes in the sunshine, loses its superabundant oxygen ; and by the hydrogen being retained the skin becomes *tanned* yellow. Though this must occur in less quantity in animals, as they perspire so much less
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than vegetables ; and the greatest part of their perspired matter, which exhales from the lungs, is not exposed to the sun's light. In proof of this it must be observed, that both vegetable and animal substances become bleached white by the sun-beams and water, when they are dead, as cabbage-stalks, bones, ivory, tallow, bees-wax, linen and cotton cloth ; and hence, I suppose, the copper coloured natives of sunny countries might become etiolated, or blanched, by being kept from their infancy in the dark, or removed for a few generations to more northern climates.

It is probable, that on a sunny morning much pure air becomes separated from the dew by means of the points of vegetables, on which it adheres, and much inflammable air imbibed by the vegetable, or combined with it ; and, by the sun's light thus decomposing water, the effects of it in bleaching linen seem to depend ; the water is decomposed by the light at the ends or points of the cotton or thread ; and the vital air unites with the phlogistic or colouring matters of the cloth ; and produces a new acid, which is either itself colourless, or washes out ; at the same time the hydrogen or inflammable part of the water escapes. Hence there seems a reason, why cotton bleaches so much sooner than linen ; viz. because its fibres are three or four times shorter, and therefore protrude so many more points ; which seem to facilitate the liberation of the vital air from the inflammable part of the water.

A sun-flower three feet and a half high, according to the experiment of Dr. Hales, perspired two pints in one day, (vegetable statics) which is many times as much in proportion to its surface, as is perspired from the surface and lungs of animal bodies ; it follows, that the vital air, liberated from the surface of plants by the sunshine, must much exceed the quantity of it absorbed by their respiration ; and that hence they improve the air, in which they live, during the light part of the day ; and thus blanched vegetables will sooner become

tanned into green by the sun's light, than etiolated animal bodies will become *tanned* yellow by the same means.

Lastly. This retention of the hydrogen on the skins of vegetables and animals, when their perspirable matter is decomposed by the sun's light, and by which the former becomes green, and the latter yellow, is evidently owing to the power of life; because when either of them are dead, the action of the sunshine on the water sprinkled on them again blanches them, or bleaches them white.

It is hence evident, that the curious discovery of Dr. Priestley, that his green vegetable matter, and other aquatic plants, gave out vital air, when the sun shone upon them; and the leaves of other plants did the same when immersed in water, as observed by Mr. Ingenhouz, refer to the perspiration of vegetables, not to their respiration. Because Dr. Priestley observed the pure air to come from both sides of the leaves, and even from the stalks of a water-flag, whereas one side of the leaf only serves the office of lungs, and certainly not the stalks. *Exper. on Air, Vol. III.* And thus in respect to the circumstance, in which plants and animals seemed the farthest removed from each other, I mean in their supposed mode of respiration, by which one was believed to purify the air, which the other had injured, they seem to differ only in degree; and the analogy between them remains unbroken.

4. The contest for light, as well as for air, which is so visible in the growth of vegetables, as described in *Botanic Garden, Vol. II.* note on *cuscuta*, shews the former to be of great consequence to their existence as well as the latter. Thus many flowers follow the sun during the course of the day by the nutation of the stalks, not by the rotation of them, as observed in the sun-flower by Dr. Hales; and the leaves of all plants endeavour to turn their upper surface to the light, which is their respiratory organ, or lungs, as shewn in *Sect. IV.*

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The great use of all plants turning their upper surfaces of their leaves to the light is thus intelligible ; the water perspired from those surfaces is hyper-oxygenated ; and, as it escapes from the sharp edges of the mouths of the perspiring vessels, when acted upon by the sun's light, gives out oxygen ; which oxygen, thus liberated from the perspired water, and added to that of the common atmosphere, presents to the respiratory terminations of the pulmonary arteries on the upper surfaces of leaves an atmosphere more replete with vital air.

This necessity of light to the respiration of vegetables is so great, that there is reason to believe, that many plants do not respire during the night, but exist in a torpid state like winter sleeping insects. Thus the mimosa, sensible plant, and many others, close the upper surfaces of their opposite leaves together during the night, and thus preclude them both from the air and light. And the internal surfaces of innumerable flowers, which are their respiratory organs, are closed during the night, and thus unexposed both to light and air.

The fungi nevertheless, which are termed vegetables, because they are fixed to the earth, or to the stones, or trees, or timber, where they are found, can exist without light or much air ; as appears in the truffle, which never appears above ground ; and by other fungi, which grow in dark cellars ; and in esculent mushrooms, which are cultivated beneath beds of straw. From this circumstance of their existing without light, and from their smell of volatile alkali, like burnt feathers, when they are burnt, and from their taste when cooked and eaten, they seem to approximate to the animal kingdom.

5. Lastly. It may nevertheless be suspected, that in many of the experiments of Dr. Priestley and Dr. Ingenhouz, the production of vital air might be simply owing to the action of the sun's light on the water, in which the vegetables were immersed, like that from the silk in the experiment of Count Rumford ; and that the fine points, or sharp edges of those bodies, contributed only to facilitate the
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the liberation of it, when exposed to the sunshine, which thus dif-oxygenate the water by their united effect.

This appears on immersing a dry hairy leaf in water fresh from a pump, innumerable globules like quicksilver appear on almost every point; for the extremities of these points attract the particles of water less forcibly, than those particles attract each other; hence the contained air, whose elasticity was but just balanced by the attractive power of the surrounding particles of water to each other, finds at the point of each fibre a place, where the resistance to its expansion is less; and in consequence it there expands, and becomes a bubble of air. It is easy to foresee, that the rays of the sunshine, by being refracted and in part reflected by the two surfaces of these minute air-bubbles, must impart to them much more heat than to the transparent water; and thus facilitate their ascent by further expanding them; and that the points of vegetables attract the particles of water less, than they attract each other, is seen by the spherical form of dew-drops on the points of grass.

6. It may be added in this place, that there may also be a fallacy in the supposed results of those experiments, where plants have been confined in hydrogen or azote mixed with atmospheric air; and have been believed to have vegetated more vigorously, and to have meliorated the air. In these experiments I suspect, that the impure part of the air was attracted by the water, and taken up by the absorbents of the roots of the plants from the water, rather than by the absorbents of their leaves or stems in the air; and that the melioration of the air was occasioned, as above described, by the action of the light on the water perspired from the surface of the plant, or liberated by its points from the water, with which part of it was covered. This is rendered more probable, because plants and seeds in the experiments of others ceased to vegetate in those gasses, which were totally deprived of oxygen, as in M. Scheele's experiments on the growth of seeds.

II. 1. The

II. 1. The fluid matter of heat is one of the most extensive elements in nature, perhaps next to that of gravitation ; all other bodies are immersed in it, and are preserved in their present state of solidity or fluidity by the different attraction of their particles to the matter of heat, which thus counteracts the powers of gravitation, and of chemical affinity, which would otherwise compress them into one solid chaotic mass !

Since all known bodies are contractible into less space by depriving them of some portion of their heat ; and as there is no part of nature totally deprived of heat ; there is reason to believe, that the particles of bodies do not touch, but are held towards each other by their self-attraction, or recede from each other by their attraction to the mass of heat, which surrounds them ; and thus exist in an equilibrium between these two powers.

If more of the matter of heat be applied to them, they recede farther from each other, and become fluid ; if still more be applied, they take an aerial form, and are termed gasses ; and it is probable, that the ethereal fluid of electricity may also be diffused with heat, as well as the ethereal fluid of light.

Thus when water is heated to a certain degree, it would instantly assume the form of steam, but for the pressure of the atmosphere ; which prevents this change from taking place so easily ; the same is true of quicksilver, diamonds, and of perhaps all other bodies in nature ; they would first become fluid, and then aeriform, by appropriated degrees of heat. On the contrary, this elastic matter of heat, termed *Calorique* in the new nomenclature of the French academicians, is liable to become consolidated itself in its combinations with some bodies, as certainly in nitre, and probably in combustible bodies, as sulphur and charcoal.

This combined heat is universally set at liberty in the production of acids by the union of oxygen with all inflammable bodies, as shewn in Sect. XII. 1. It is also taken from some bodies by the vicinity of

very cold ones, as water when frozen loses suddenly a part of its combined heat, at the moment it becomes ice.

2. It is evident, that without fluidity the blood or juices can not circulate in animal or in vegetable vessels; whence so great a diminution of heat as to produce frost on this account would destroy them if long continued; at the same time too great a deduction of heat is known to destroy the irritability of animal as well as of vegetable fibres, and must on this account also prevent the circulation of their fluids, and occasion the mortification of parts of them, or the death of the whole. But when fluids are converted into ice, the bulk of them is enlarged to a considerable degree, and that with such violence as to burst iron vessels, as bombs, which are filled with water. Whence in this manner also frost destroys those parts of vegetables, which are most succulent; as the early shoots of ash trees, and other young plants, are frequently destroyed in the beginning of May by a frosty night.

The vessels of these succulent parts of plants are distended and burst by the expansion of their frozen fluids; while the drier or more resinous vegetables, as pines, yews, laurels, and other evergreens, are less liable to injury from cold. The trees in valleys are on this account more liable to injury by the vernal frosts, than those on eminences; because their early succulent shoots appear sooner in the year.

Another method, by which the act of freezing may destroy vegetable life, may be by separating some part of their fluids from other parts of them. Thus when wine, or vinegar, or salt and water, or clay diffused in water, and perhaps milk, are frozen; the watery part, as it congeals, protrudes from its forming crystals the spirit, the acid, the salt, the clay, and probably the opaque particles of the milk; and by a similar process on vegetable and perhaps on animal fluids, when exposed to great cold, they may be rendered unfit for future circulation or life. See Sect. XV. 4. 1.

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The expansion of ice nevertheless well accounts for the greater mischief which is sometimes done by vernal frost, when preceded by much rain, or mist, or dew, as by hoar-frost, than by the dry frosts without rime, called black frosts; as the vegetable vessels are then fuller of fluids. But when mist or dew attends a frosty night, but has not preceded it, I suppose a hoar frost may be less injurious than a black frost; as the case of ice on the buds of trees, or on young grass, being instantly produced, covers them with a bad conductor of heat, and prevents them from being exposed to so great cold, as in the continuance of a black frost without hoar or rime. See Sect. XV. 3. 5.

Mr. Laurence, in a letter to Mr. Bradley, complains, that the dale-mist attended with a frost on May-day had destroyed all his tender fruits; though there was a sharper frost the night before without a mist, that did him no injury; and adds, that a garden not a stone's throw from his own on a higher situation, being above the dale-mist, had received no damage. Bradley, V. II. p. 232. From this instructive fact it appears, that very low situations even in this cold climate are not proper for the purposes of a garden. And on the contrary, very high situations are equally improper on account of their greater cold, and the consequent backwardness of their vegetable products. See Sect. XV. 3. 5.

Hence fruit trees against a wall, which are covered with coping stones projecting six inches over them, are less injured by the vernal frosts; because their being thus sheltered from the descending night-dews has prevented them from being moist at the time, they were frozen; which circumstance has given rise to a vulgar error amongst gardeners, who suppose frost to descend.

Hence as the freezing winds of this country are from the north-east, a gardener should extend his rows of young peas and beans from the south-east to the north-west, and raise a mound of earth behind them, and might shelter them occasionally with straw, placed on the

ground behind the young plants, and supported a few inches over them in front by poles placed horizontally over the rows; remembering the old proverb,

The wind from north-east
Destroys man and beast;
The wind from south-west
Is always the best.

The immediate cause of the coldness of the N. E. winds is, that they consist of regions of air brought from the north over evaporating ice, and gain an apparent easterly direction, because they arrive at a part of the surface of the earth, which moves with greater velocity, than the surface of the part of the earth, they come from. So on the contrary the S.W. winds are warm, as they consist of regions of air brought from the south, and gain an apparent westerly direction, because they arrive at a part of the earth's surface, which moves slower than the surface nearer the equator, whence they came, and of which they had previously acquired the velocity.

As the common heat of the earth in this climate is 48 degrees, those tender trees, which will bear bending down, are easily secured from the frost by spreading them upon the ground, and covering them with straw or fern. This particularly suits fig-trees, as they are very flexible, and as they are furnished with an acrid juice, which defends them from insects; but I have nevertheless found them in this situation much eaten by mice.

It has been believed by many, that frost meliorates the ground; but it is now well known, that ice contains no nitrous particles, as was formerly supposed; and that though frost by enlarging the bulk of some moist soils may leave them more porous for a time after the thaw; yet as the water exhales, the soil becomes as hard as before, being pressed together by the incumbent atmosphere. And from an observation of Mr. Kirwan's, mentioned in Section XV. 4. 1. it appears,

pears, that moist clay becomes denser or more solid by being frozen ; and if this should not occur, yet it would quickly become as solid as before by the self-attraction of its particles, called *setting* by the potters ; as well as by the pressure of the atmosphere ; as its water exhales, and leaves vacuities between its particles. Add to this, that on the coasts of Africa, where frost is unknown, the fertility of the soil is much superior to our own.

In respect to the commonly supposed salubrity of frosty seasons to mankind, and to other animals, the bills of mortality are an evidence in the negative in respect to mankind, as in long frosts many weakly and old people perish from debility, occasioned by the diminished heat not being sufficient to excite into action their vessels previously too irritable ; and many birds, and other wild animals, and tender vegetables, perish benumbed by the degree and continuance of the cold.

It should however be observed, as frosty air is always dry, except when frozen mists dissolve, as they adhere to the warmer skins of animals, that it does not generally affect us with so great a sensation of cold, as when air near the freezing point is loaded with moisture ; as the moisture of such air is perpetually evaporating from our skins, and produces on them a degree of cold greater than the simple contact of dry air produces, when it is but a little beneath the freezing point. Hence frosty air is more agreeable to those young or strong people, who can keep themselves warm by exercise ; that is, who can generate heat by increased secretions. But severe and continued frosts destroy the old and infirm, who cannot use much exertion ; and the children of the poor, who want both food, fire, and clothing, in this harsh climate.

It may nevertheless be true, that snows of long duration in our winters may be less injurious to vegetation than great rains and shorter frosts. 1. Because great rains carry down many thousand pounds worth of the best manure into the sea ; whereas snow dissolves gradually, the upper surface, as it thaws, sliding over the under part,

which remains frozen, and thence carries away less from the land into the rivers; whence a snow flood may be distinguished from a rain flood by the transparency of the water.

Secondly. Snow protects vegetables from the severity of the frost; since it is generally in a state of thaw, where it is in contact with the earth; as the earth's heat is 48 degrees, and that of thawing snow is 32°. The plants between them are generally kept in a degree of heat about 40, by which many of them are preserved. On this account some plants from Siberia were said to perish by the frosts at Upsal; because the snows did not commence at the same time as in the colder climate, from which they were brought.

Thus the lichen *rangiferinus*, coral-moss, vegetates beneath the snow in Siberia, where the degree of heat is always about 40; that is in the middle between the freezing point and the common heat of the earth. And as this vegetable is for many months of the winter the sole food of the rein-deer, who digs furrows in the snow to find it; and as the milk and flesh of this animal is almost the only sustenance, which can be procured by the natives during the long winters of those higher latitudes, this moss may be said to support some millions of mankind.

Snow protects vegetables, that are covered by it, from cold, both because it is a bad conductor of heat itself, and contains much air in its pores. When living animals are buried in snow, as sheep, or hares, the water, which their warmth produces, becomes absorbed into the surrounding snow by capillary attraction, and the creatures are not moistened by its dropping on them; but the cavity enlarges, as the snow dissolves, affording them both a dry and a warm habitation. If this was generally known, many cold and weary travellers in snowy nights might be saved by covering themselves with snow instead of endeavouring to proceed.

It should be added that Haïssenfratz has endeavoured to shew by ingenious chemical experiments, that rain water and snow contain
both

both of them a redundancy of oxygen compared with river water, which they may have acquired in their descent through the atmosphere; and that as oxygen is shewn by the experiments of Ingenhouz and Senebier to promote the growth of feeds and of plants, he concludes, that rain water and snow promote vegetation in a much greater degree than river water or ice, which seems to accord with the popular observations on this subject.

3. Mr. John Hunter by applying thermometers to the internal parts of vegetables newly opened discovered, that they possessed in frosty seasons a degree of heat above that of the atmosphere, though less than that of cold blooded animals. Whence another deleterious effect of cold on vegetable bodies must be by destroying their irritability, and by that means stopping the absorption and circulation of their juices; in the same manner as is seen in the pale benumbed fingers of some people, when exposed to the cold; and which is the immediate cause of death in those, who perish in the snow in winter, which occurs long before their fluids are frozen.

The necessity of a certain degree of heat to produce or to preserve the activity of the absorbent vessels of vegetables is well evinced by the experiments of Hales and Duhamel on the rising sap of vines in the vernal months. On a frosty day, when the sun shone on one of those wounded trees, the sap flowed on the south side of the tree, but not on the north side. *Physique des arbres*, Vol. II. p. 258. M. Duhamel further observes, that the maples in Canada, where the frost is long and severe, begin to bleed, when wounded with the first thaw, and stop again, when it freezes; and that this in frosty days occurs only on the south side of the tree.

This acquaints us, that one of the principal properties of heat in respect to organic bodies, whether of vegetables or animals, consists in its acting as a stimulus; and that in a greater quantity than that, which the organized being has been accustomed to, it acts as an excess of stimulus; and thus increases the activity of the system

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in respect to the absorption of its food, circulation of its juices, and quantity of its secretions, and consequently to its more rapid growth; but all increase of stimulus becomes injurious by its excess, and is certainly followed by debility; as is seen in those of our own species, who are habitually kept in too warm rooms, or are accustomed to drink intoxicating liquors.

Hence a wise gardener must regard the acquired habits of tender vegetables; the inhabitants of his green house, and those plants, which have been exposed to a greater heat for any length of time, should be gradually cooled, and watered with subtepid water; since exposing them to the cold of this climate is otherwise liable to destroy their irritability and occasion their death.

4. The great cold produced by evaporation is now well understood. In all chemical processes, where aerial or fluid bodies become consolidated, a part of the heat, which was before latent, becomes pressed out from the uniting particles; as in the instant that water freezes, or that water unites with quick lime. On the reverse, when solid bodies become fluid, or fluid ones become aerial, heat is absorbed by the solution; whence it may be said in popular language, that all chemical combinations produce heat, and all chemical solutions produce cold. This should teach the careful gardener not to water tender vegetables in the heat of the sunshine, or in a warm dry wind; lest the hasty evaporation should produce so much cold as to destroy them; and that more certainly from their having been previously too much stimulated by heat, and in consequence their power of life, or irritability, having been already diminished; as further spoken of in Sect. XIV. 2. 2.

III. 1. The mechanical theory of electricity invented by Dr. Franklin is believed by some philosophers not so well to explain the various phenomena of electricity, as may be accomplished by an hypothesis of the existence of two electric fluids diffused together, and strongly attracting each other, one of them to be called vitreous, and

the other resinous, electricity. The latter opinion I am inclined to espouse, but shall not here enter into a detail of the theory; but shall only observe, that the experiments on vegetation have been principally made with the accumulation of the vitreous electricity only, and the consequent exclusion of the resinous; that is, with what is commonly termed positive electricity, and not with what is termed negative electricity. It is therefore to be wished, that some future experiments may be made with the resinous or negative electricity in preference to the vitreous or positive electricity, or with both of them alternately or comparatively.

The influence of positive or vitreous electricity in forwarding the germination of plants and their growth seems to be pretty well established; though Mr. Ingenhouz did not succeed in his experiments, and thence doubts the success of those of others; and though M. Rouland, from his new experiments believes, that neither positive nor negative electricity increases vegetation; both which philosophers had previously been supporters of the contrary doctrine; for many other naturalists have since repeated their experiments relative to this object, and their new results have confirmed their former ones. Mr. D'Ormev and the two Roziers have found the same success in numerous experiments, which they have made in the two last years; and Mr. Carmoy has shewn in a convincing manner, that electricity accelerates germination.

Mr. D'Ormev not only found various seeds to vegetate sooner, and to grow taller, which were put upon his insulated table, and supplied with electricity; but also that silk-worms began to spin much sooner, which were kept electrified, than those of the same hatch, which were kept in the same place and manner, except that they were not electrified. These experiments of Mr. D'Ormev are detailed at length in the *Journal de Physique* of Rozier, Tom. XXXV. p. 270.

Mr. Bartholon, who had before written a tract on this subject, and proposed

proposed ingenious methods for applying electricity to agriculture and gardening, has also repeated a numerous set of experiments; and shews, that natural electricity as well as the artificial increases the growth of plants, and the germination of seeds; and opposes Mr. Ingenhouz by very numerous and conclusive facts. *Ib.* Tom. XXXV. p. 401.

My friend Mr. D. Billsborrow in June 1797 sowed mustard-seed in four garden pots at Mr. Hartop's at Dalby Hall in Leicestershire. He subjected one of these to positive or vitreous electricity, and another to negative or resinous electricity, and observed that the seeds in the pot subjected to the negative or resinous electricity germinated a day before the pot subjected to positive or vitreous electricity, and both of them much before the two pots, which were not electrified, but otherwise exposed to the same circumstances.

Nor do the injuries occasionally received from lightning in its passage through trees or corn fields from or to the earth or clouds, which are mentioned in Sect. XIV. 2. 3. in the least invalidate this opinion of its general utility as well as that of the fluid element of heat; for the excess of the most salutary stimuli become deleterious both to vegetable and animal bodies.

2. Since by the late discoveries in chemistry there is reason to believe, that water is decomposed in the vessels of vegetables; and that the hydrogen, or inflammable air, of which it in part consists, contributes to the nourishment of the plant, and to the production of its oils, resins, gums, sugar, &c. And lastly, as electricity has by late experiments been found to decompose water into the two airs, termed oxygen and hydrogen, there is a powerful analogy to induce us to believe, that it accelerates or contributes to the growth of vegetation; and like heat may possibly enter into combination with many bodies, or form the basis of some yet unanalysed acid.

3. The solution of water in air or in caloric seems to acquire electric matter at the same time, as appears from an experiment of
Mr.

Mr. Bennet. He put some live coals into an insulated funnel of metal, and throwing on them a little water, observed that the ascending steam was electrified plus; and the water, which descended through the funnel, was electrified minus. Hence it appears, that though clouds by their change of form may sometimes become electrified minus, yet they have in general an accumulation of positive electricity. This accumulation of electric matter also evidently contributes to support the atmospheric vapour, when it is condensed into the form of clouds; because it is seen to descend rapidly, after the flashes of lightning have diminished its quantity.

According to the theory of Mr. Lavoisier concerning the composition and decomposition of water, there would seem another source of thunder-showers; and that is, that the two gasses termed oxygen gas, or vital air, and hydrogen gas, or inflammable air, may exist in the summer atmosphere in a state of mixture, but not of combination; and that the electric spark, or flash of lightning, may combine them, and produce water instantaneously.

4. A profitable application of electricity by the gardener or agricultor to promote the growth of plants is not yet discovered; it is nevertheless probable, that in dry seasons the erection of numerous metallic points on the surface of the ground, but a few feet high, might in the night time contribute to precipitate the dew by facilitating the passage of electricity from the air into the earth; and that an erection of such points higher in the air by means of wires wrapped round tall rods, like angle rods, or elevated on buildings, might frequently precipitate showers from the higher parts of the atmosphere.

And lastly, that such points erected in gardens might promote a quicker vegetation of the plants in their vicinity by supplying them more abundantly with the electric ether; if the events of the experiments of the philosophers above mentioned are to be depended upon, which may at least be worth a further trial.

5. For the purpose of keeping a few flower-pots perpetually subject to more abundant electricity, Mr. Bennet of Wirksworth in Derbyshire affixed a small apparatus to the pendulum of a clock, as described below with a plate; but has not yet sufficiently attended to it to determine its effect on vegetation.

PLATE VIII.

PLATE VIII.

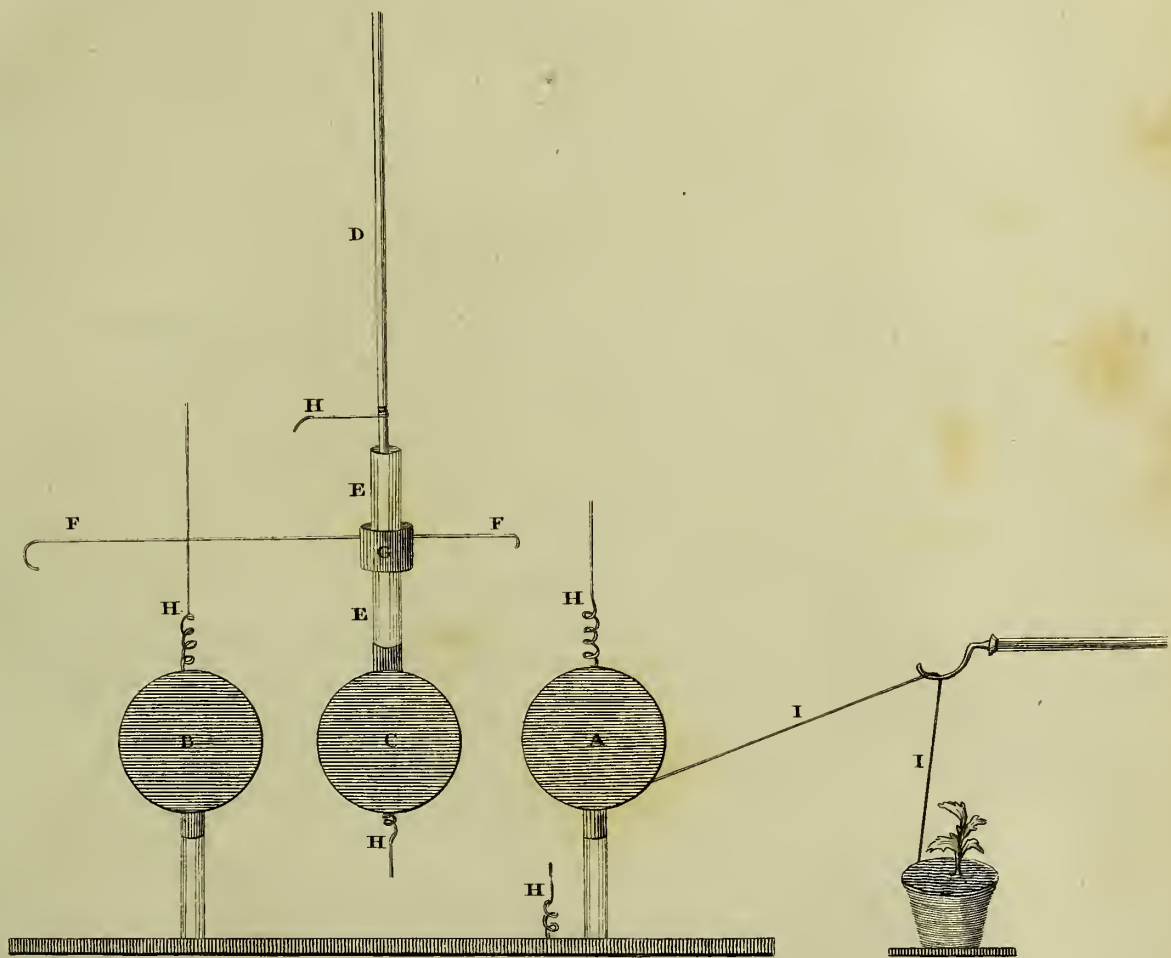
Shews the structure of Mr. Bennet's electric Doubler, applied to the pendulum of a clock for the purpose of subjecting a flower-pot to perpetual positive or negative electricity.

A the brass plate, which is always insulated by its glass pedestal, on which the electricity is accumulated. B the brass plate, which becomes electrified by the influence of the moving plate C, which is also insulated. D the pendulum wire. C is insulated by the glass-tube E E. The wire F F is also insulated by the same glass, being fastened to the middle of it by a brass socket at G. H H H H H are wires to connect the plates with each other, or with the earth. I I a string to be carried from the plate A over insulated hooks to any part of a room, or to an insulated flower-pot.

Now if A be positive, and C moves, till it be parallel to it, and the wires at the bottom touch each other, then C becomes negative, and moving till it be parallel to B, and its wire touched by the uppermost H, then B becomes positive; and when C returns to A, the electricity of A and B becomes united by means of the insulated wire F F touching H H. The longer end of F is bent so as not to touch the wire of B, till the end is brought to it. Thus the positive electricity of A is increased.

The wires are curled into several rings to make them more elastic, as otherwise they would soon be pushed out of their places, and the proper contacts not occur. The plates A and B may be fixed on heavy pedestals, that they may be moved upon a shelf to a proper distance from the plate, which hangs by the pendulum wire. The heavier the pendulum and the larger the plates, the more electricity may be accumulated. With my small apparatus fixed to a Dutch wooden clock sparks are sometimes produced between the plates, and sometimes the clock has been stopped by their attraction to each other. Perhaps the plates should not be circular, but something like a lady's fan, when expanded, the bottom being a part of the curve described by the moving pendulum, with the sides directed towards the point on which it moves.

This drawing and description of his Pendulum Doubler was sent me by Mr. Bennet of Wirksworth, and is referred to at the end of Sect. XIII. of this work. If another insulated flower-pot was connected with the plate B instead of the wire at the uppermost H, perhaps it might be kept in a state of minus, or negative electricity, at the same time that the other flower-pot was kept in a state of plus or positive electricity.



S E C T. XIV.

DISEASES OF PLANTS.

- I. Diseases from internal causes. 1. *Diseased irritability.* Irritability derived from oxygen. Exhausted by too great stimulus. Shade apricot flowers from the sun. Much water after a hot day injurious. Irritability accumulated by less stimulus. Experiment on euphorbia. Habits of plants brought from the south. Taken to America. In the bleeding season. Vines in hot-houses. Habits of plants. Irritability greater after being exposed to much cold, less after much heat. Greatest in the morning. Hybernating animals. Variation of heat contributes to health.
2. *Erysiphe mildew.* A sessile fungus. Give light and ventilation. Drain the land. Sow early. Rubigo, rust. Probably another fungus. *Uredo frumenti.* Blight.
4. *Clavus, ergot.* On rye, which it renders unwholesome. Ascribed to insects by Dubamel.
5. *Ustilago, smut.* Ascribed to insects by Linneus. Is probably owing to want of impregnation. How prevented.
6. *Gangrena, canker.* Affects apple-trees from old grafts. From wounds. Bind living bark on the wound. Or paint the alburnum.
7. *Suffusio mellita, honey-dew.* If occasioned by the aphid? Succeeded by a black powder.
8. *Exsudatio miliaris, miliary sweat.* On vines in hot-houses from too great heat in confined air.
9. *Fluxus umbilicalis, sap-flow.* From wounds in spring, and after midsummer. Bind on sponge. Strangulate with wire.
10. *Secretio gummosa, gum secretion.* Bind on lead. Sponge, Indian rubber. Apply solution of green vitriol. Bind on a new bark.
- II. Diseases from external elements. 1. Draught and moisture. 2. Heat and cold. Shelter early blossoms from the sunshine. 3. Lightning. Injures trees and wheat fields. By destroying their irritability, like the stimulus of some poisons. By bursting their vessels. How to prevent. 4. Light. Etiolation of sea-cale. 5. Of acid clay. Of sterile sand. 6. Noxious exhalations, from lead-works, and lime-kilns. 7. Poisons of arsenic, muriatic acid. 8. Condiments. Alcohol. Opium. Sea-salt. Its use and effect on vegetables. Use in the worm of sheep. 9. External injuries. Wound grape-

grape-stalks. Caprification. Pluck pears to ripen them. III. Diseases from insects. 1. *From their nests and young. On roses, on quince-blossoms, on aconite.* 2. *Aphis on peach trees. Slugs prefer withered leaves. Cows eat withered thistles. The poison of yew leaves. History of the aphis. Means of destroying them. Aphidivorous larva and fly.* 3. *Caterpillars on apple-trees and goose-berries. Burn the leaves. Put a fringe round gooseberry-trees. Destroy white butterflies. Cabbage caterpillars destroyed by ichneumon fly.* 4. *Insects in hot-houses. Smoke of sulphur injurious to trees.* 5. *Beetles beneath the soil. Snails. Slugs. Roll turnips before sun-rise. Slugs prevented by lime or salt. Caught by a board. Fly on turnips. Roll them. Steep turnip seeds in liquid manure as in China.* 6. *Beetles. Fern-chaffer. Destroys crops of wheat. Sow wheat shallow. Roll it, or strew salt in fine powder. Thrips physaphus on wheat. Corn butterfly. May-chaffers on hedges. Locust. Encourage hedge-birds, larks, rooks, hedge-hogs. Some caterpillars wholesome to eat, others poisonous. All very hardy and difficult to destroy.* IV. Destruction by vermin. 1. *Mice. Tussocks of wheat from their granaries. Encourage the breed of owls.* 2. *Water-rats like beavers, how driven from a fish-pond. They eat vegetables. Are attracted by scents. How to poison them. How to entrap them.* 3. *Moles never drink. Sometimes swim. Work before sun-rise. How to destroy them by traps.*

THE diseases of vegetables may be divided into those, which appear to originate from internal causes, those from the external elements, and those from the nidifications or depredations of insects; to which may be added the depredations of other animals. We shall begin with diseased irritability.

DISEASES FROM INTERNAL CAUSES.

I. 1. It has already been shewn, that the buds of vegetables are individual beings, and constitute an inferior order of animals; and that they possess irritability, and sensibility, and voluntariness, and have associations of motion; as explained in *Zoonomia*, Vol. I. Sect. XIII. But as the three latter kinds of excitability are possessed in a so much less

less degree by vegetable buds, than by more perfect animals, we shall only consider the diseases of their irritability.

M. Girtannir endeavoured to shew, that animal irritability originates from the oxygen, which constitutes somewhat less than a third of the atmosphere, which they breathe. And M. Van Ussler has applied the same idea to vegetable life; and has endeavoured to shew, that their irritability also originates from the oxygen, which they acquire either by the respiration of their leaves, or by the absorption of their roots. And indeed, as respiration is every minute necessary to animal life, there is reason to believe, that something immediately necessary to the existence of life is acquired by the lungs of animals from the atmosphere rather than from the food, which they digest; and that this, which is believed to be the oxygen only, is mixed with the blood, and separated again from it by the brain, and spinal marrow, after having undergone some change in the circulation or secretion of it.

In the same manner it is not improbable, but that the spirit of vegetation may have a similar origin, probably from the uncombined oxygen of the air, respired by the upper surfaces of their leaves; and not from that, which is absorbed by their roots in a more combined state; and that this oxygen is again separated from their juices by the sensorium, or brain, of each individual bud, after having undergone some change in the circulation or secretion of it. See Sect. IV.

1. 2.

The circumstances attending vegetable irritability are similar to those belonging to the irritability of animals upon a less extensive scale, as detailed in *Zoonomia*, Vol. I. Sect. XII.

When vegetable fibres have been long stimulated more than natural or usual by increase of heat, the spirit of vegetation becomes exhausted; and in consequence a slighter degree of cold will destroy them; because their fibres after having been long excited by a greater stimulus will cease to act on the application of one, which is much

less; whence after hot days tender plants are more liable to be destroyed by the coldness of the night. Whence in more northern climates the gardeners shade their tender vegetables, as the flowers of apricots, in the spring-frosts from the meridian sun, as well as from the coldness of the night; which is generally the greatest about an hour before sunrise.

In the hot days of June 1798 I twice observed several rows of garden beans become quite sickly, and many of them to die, from being flooded for an hour or two with water from a canal in the neighbourhood; which I ascribed more to the sudden application of too great cold, after being much enfeebled, or rendered inirritable, by the excessive heat of the season, than to the too copious supply of water to the dry ground; to which should be added, that some plants are more liable to be thus injured than others; as the strawberries, young cabbage plants, and onions, which were in the same situation, received benefit and not deterioration by being thus occasionally watered in that dry season.

On the contrary, when plants have been long exposed to a less stimulus of heat than natural or usual, the spirit of vegetation becomes accumulated; and if they are too suddenly subjected to much greater heat, their too great increase of action induces inflammation, and consequent mortification, and death; as occurs to those people, who have had too much warmth applied to their frozen limbs. Experiments of this kind were instituted by Van Ussur; he increased the irritability of euphorbia peplus and esula by secluding light and heat from them; and, when he exposed them to a meridian sun, they became gangrenous, and died in a short time.

This greater or less irritability of plants is to be ascribed to their previous habits in respect to the stimulus of greater or less heat. Thus the times of the appearance of vegetables in the spring seem occasionally to be influenced by their previously acquired habits, as well as by their present sensibility to heat. For the roots of potatoes, onions,
will

will germinate with much less heat in the spring than in the autumn; as is easily observable, where these roots are stored for use; and hence malt is best made in the spring, as the barley will then germinate with a less degree of heat.

The grains and roots brought from more southern latitudes germinate here sooner than those, which are brought from more northern ones, owing to their acquired habits. Fordyce on Agriculture. It was observed by one of the scholars of Linneus, that the apple trees sent from hence to New England blossomed for a few years too early for that climate, and bore no fruit; but afterwards learnt to accommodate themselves to their new situation. (Kalm's Travels.) Vines in grape houses, which have been exposed to the winter's cold, will become forwarder and more vigorous than those, which have been kept during the winter in the house. (Kennedy on Gardening.) This accounts for the very rapid vegetation in the northern latitudes after the solution of the snows.

The increase of the irritability of plants in respect to heat, after having been previously exposed to cold, is farther illustrated by an experiment of Dr. Walker's. He cut apertures into a birch-tree at different heights; and on the 26th of March some of these apertures bled, or oozed with the sap-juice, when the thermometer was at 39; which same apertures did not bleed on the 13th of March, when the thermometer was at 44. The reason of this I apprehend was, because on the night of the 25th of March the thermometer was as low as 34; whereas on the night of the 12th of March it was at 41; though the ingenious author ascribes it to another cause. Transact. of the Royal Society of Edinburgh, V. I. p. 19.

There is an observation in Mr. Tull's work, which he ingeniously ascribes to the acquired habits of plants. "By the extremely hard winter of the year 1708 or 1709, some lucern in Languedoc was killed, along with all the olive trees and walnut trees by the severity of the season; though I could not hear that one walnut tree was

killed in England. Perhaps those in France having been accustomed to much hotter summers were unable to endure the rigour of the same winter, that did not destroy the same plants in England." Horfe-hoeing Husbandry, Ch. XIII. p. 201.

By adapted experiments Medicus is said to have found, that the irritability of plants is greater in the morning, less in the middle of the day, and much less in the evening. And Von Ussler found, that their irritability in respect to their contractions was increased in cool and rainy weather. Observ. on Plants by Schmeisser. Edinb. So the parts of animals become more sensible to heat after having been previously exposed to cold; as our hands glow on coming into the house after having for a while been immersed in snow; and many insects, and other animals, which hide themselves in the earth, and sleep during the winter, were observed by M. Spallanzani to disappear at a season, when the heat of the atmosphere was much higher than in the spring, when they again made their appearance.

Hence it follows, that plants, which are kept in a warm room during winter, should occasionally be exposed to cooler air to increase their irritability; as otherwise their growth in the spring is observed to be very tardy. Mankind for the same reason requires the perpetual variations of the heat of the atmosphere to preserve or restore the irritability, and consequent activity, of the system. Whence the health and energy of men are greater, and their lives longer, in this variable island, than in the tropical continents, which possess greater warmth, and less variation of weather.

2. Linneus in the *Philosophia Botanica* has given names to but four internal diseases, eurisphe, mildew; rubigo, rust; clavus, ergot, or spur; and ustilago, smut; to which may be added many others as described below.

Erysiphe, a white mucor, or mould, or mildew, with sessile tawny heads, with which the leaves are sprinkled; this is frequent in humulus, hop; lamium, dead nettle; gallopolis, arch-angel; lithospermum,

thospermum, stone-feed; and acer, maple. This mucor is a plant of the fungus kind, which will grow without light, or change of air, like other funguses; and with its roots penetrates the vessels of the vegetables to which it adheres. But these vessels are probably previously injured by internal disease. The methods of preventing or destroying it must consist in thinning the plant, or removing those in its vicinity, so as to admit more light, and greater ventilation, which may at the same time eradicate the mildew, and restore the internal vigour of the plant.

As the greater dampness of some land supplies one permanent cause of mildew, as well as its being too much overshadowed by thick foliage, the methods of prevention must consist in properly draining the land, and using drier kinds of manure, as coal-ashes and bone-ashes, as well as by thinning the crops. And lastly, it is recommended to sow early in the season for the purpose of procuring forward crops; as this disease is said more to injure late crops owing to the greater dampness of the ground in autumn.

3. Rubigo, rust, a ferruginous powder sprinkled under the leaves, frequent in alchemilla, lady's mantle, rubus saxatilis, effula degener; and particularly in fenecio or jacobæa; and especially in a burnt woody soil.

This is probably another fungus similar to the former, or to some kinds of lichen, which grows beneath the leaves of vegetables previously diseased, and may probably be prevented or destroyed by exposing the plant to more light, and greater ventilation, as in the mucor above mentioned.

An account is given by Mr. Lambert in the Transactions of the Linnean Society, Vol. IV. of a disease which may probably be somewhat similar to the rubigo, which he calls uredo frumenti, or blight of wheat, and describes it to be a fungus, which covers the stems of wheat in wet seasons, when it is nearly ripe, so as to give the field an appearance of being covered with foot. The stem of the wheat is

said to appear to be split, and the growth of the plant to be much injured. He describes the fungus to be linear-oblong, tawny-black.

4. *Clavus*, ergot, or spur, occurs when seeds grow out into large horns, black without, as in *secale*, rye, and in *carex*. This disease frequently affects the rye in France, and sometimes in England, in moist seasons, and is called ergot, spur, or horn-feed; the grain becomes considerably elongated, and is either straight or crooked, containing black meal along with the white; and is said to appear to be pierced by insects, which are supposed to cause the disease.

Mr. Duhamel ascribes it to this cause, and compares it to galls on oak-leaves; but this has not yet been established by sufficient observations. By the use of this bad grain amongst the poor, diseases have been produced, attended with great debility, and mortification of the extremities, both in France and England. *Dict. Raïson. Art. Siegle. Philos. Transact. Vol. LV. 106.*

5. *Ustilago*, smut, when the fruit instead of seed produces a black meal, as in wheat, barley, oats, *scorzonera*, *tragopogon*. Much is said on this disease in the *Dict. Raïson* of Bomare. Art. Bled, who recommends steeping the grain, before it is sown, in brine; which is generally directed to have so much salt added to the water, as may increase its specific gravity, till an egg will swim in it; or secondly, to steep the seed-wheat in lime water; or thirdly, which he thinks most efficacious, in an alkaline ley made by adding pot-ash to lime-water.

In the *systema naturæ* of Linneus under the article *Vermes*, *Zoophyta*, *Chaos ustilago*, there is a quotation from Munchhausen, that the *ustilago* is a black powder, which is found in the destroyed grains of barley, wheat, and other grasses; and in the florets of *tragopogon* *scorzonera*. And that this powder being macerated in warm water for some days passes into oblong animalcules, hyaline in respect to colour, and playing about like fish, as may be seen by a microscope; and

and are again mentioned in Linneus's dissertation on the invisible world.

There is an ingenious paper in the publications of the Bath Society, in which the author observes, that the smut in wheat only happens, when wet weather occurs at the time of the flowering of the wheat; which may burst the anthers, and wash away the farina. He thinks that steeping the wheat in brine or lime water is an ancient error, and can be of no use but to separate light wheat from that which is good.

For he found smutty ears and good ones growing from the same root; and thence it could not depend on any contagious material, or infects eggs, adhering to the seed; and in some even the same ear contained both sound and smutty corns. And lastly, that some of the corns had one end smutty, and the other sound; and he concludes, that it must be owing to the want of impregnation from the defect of the farina fecundans; and that the putrefaction succeeded the death of the grain.

From the observations of Spallanzani on leguminous plants the probability of this opinion is much confirmed. He found that the seed was produced by the female organ of the plant, long before it was impregnated; which could not happen, till the flower was open, and the anther-dust ripe. Whence it is easy to conceive, that for want of impregnation, or the vivifying principle, the wheat-corn must putrefy like the addle eggs of poultry, which are unimpregnated, and thence die, and in consequence putrefy.

If this disease of smut should become a serious evil, it might possibly be prevented by sowing the grain in distant rows; and after some days sowing other rows between them of the same, or of another kind of wheat; by which means, if wet weather should destroy the anthers of one set of rows, the alternate ones might supply farina to their stigmas, if the weather became favourable. See Sect. XVI. 8. 2.

Wheat discoloured by smut may be washed, and readily dried on

a malt kiln, and may be thus easily made marketable and equally good; for the living grain will not absorb much water in a short time; or it may be mixed with clean sand, and after being well agitated the sand may be separated by a riddle; and if necessary the same sand may be washed and dried for repeated use.

6. Besides the four internal diseases above spoken of, as mentioned by Linneus; and the uredo of Mr. Lambert, there are probably many others, which have not yet been sufficiently attended to, as the canker, gangrena; the honey-sweat, *exsudatio mellita*; the miliary sweat, *exsudatio miliaris*; the sap-flow, *fluxus umbilicalis*; and the gum secretion, *secretio gummosa*.

The canker, which may be termed *gangrena vegetabilis*, is a phagedenic ulcer of the bark; which is very destructive to apple-trees, and pear-trees, as it spreads round the trunk or branches, and destroys them.

Mr. Knight has observed this disease to be most frequent and fatal to those trees, the fruit of which has been long in fashion; as they have been perpetually propagated for a century or two by ingrafting; which he believes to be a continuation of the old tree, though nourished by a new stock; and that the canker is thus a disease of old age, like the mortification of the limbs of elderly people, and arises from the irritability of a part of the system.

But it seems more probably to be an hereditary disease, as the buds of trees being a lateral progeny, and more exactly resembling their parents, must be more liable to the diseases gradually acquired or increased by the influence of soil or climate; and have not the probability of improvement, which attends the progeny of sexual generation.

It is nevertheless frequently produced on trees by external violence, as by a stroke with a spade by a careless labourer, who is digging near them; but this probably may more easily affect the old grafts above mentioned. When a destruction of the bark is thus produced by external

ternal violence, it may possibly be cured by the application of a piece of living bark from a less valuable tree, bound on as mentioned in the next article, and in Sect. XVII. 3. 10.

The edges of these gangrenous ulcers of the bark should be nicely pared with a knife, so as to admit the air, and to prevent the depredations of insects and the lodgment of moisture, which might promote the putrefaction of the stagnant juices, and spread the gangrene; this should be so managed as only to cut away the dead lips of the wound, but not so as in the least to injure the living bark. Some thick white paint may then be smeared on the naked alburnum or sap-wood on a dry day, which may prevent insects from inserting their eggs into it, and produce maggots, which erode and destroy the wood; and may also prevent the dews and rains from rotting it. The paint should nevertheless be so spread, as not to touch the edges of the wound; as it might injure their growth by its poisonous quality; a quarter of an ounce of sublimate of mercury, hydrargyrus muriatus, rubbed with about a pound of white lead paint, might render it more noxious to insects. See Sect. XVII. 3. 9. and 10.

7. The honey-dew, which may be called *suffusio mellita*, consists of a saccharine juice, which I have supposed to be exsuded from the tree by the retrograde motions of the cutaneous lymphatic vessels, connected either with the common sap-vessels described in Sect. II. or with the umbilical vessels described in Sect. III. 2. 8. instead of its being carried forwards to increase the growth of the present leaf-buds, or to lay up nutriment for the buds, which are in their embryon state; and may thus be compared to the *diabœtes mellitus*, or to the sweating sickness of the last century.

The saccharine and nutritious quality of the honey-dew, similar to that of the sap-juice, which rises in the vernal months from the birch and maple, is evident from its taste; and from the number of bees and ants, which are said to feed on it, when it appears on some trees;

trees; and which shews, that its exudation must be considerably injurious to the tree, as before mentioned in Sect. VI. 6. 3.

In a paper written by the Abbé Boiffier de Sauvages, he describes two kinds of honey-dew; one of which he concludes to be an exudation from the tree, and the other he asserts to be the excrement of one kind of aphid, which the animal projects to the distance of some inches from its body on the leaves and ground beneath it; and which he believes the animal acquires by piercing the sap-vessels of the leaf. This paper is detailed in Wildman's work on Bees, p. 46. The circumstances are distinctly described, and by so great a philosopher as Sauvages of Montpellier, that it is difficult to doubt the authenticity of the fact. But that a material so nutritive should be produced as the excrement of an insect is so totally contrary to the strongest analogy, that it may nevertheless be suspected to be a morbid exudation from the tree; though these insects might occasionally prey upon it, and void it almost unchanged at those seasons, because the insects continued some months after the honey-dew ceased, and before it commenced, as mentioned below; and the upper surfaces of the leaves became covered with a black powder, which had before been covered with the honey-dew. And lastly, because on other trees, as on the peach and nectarine, at other seasons of the year, no honey-dew is perceived, though the aphid much abounds to the great injury of the trees.

Early this morning, June 18, 1798, I observed a remarkable honey-dew on an extensive row of nut-trees, *corylus avellana*, which grow by the side of a pond of water; the sun shone bright, and the upper surface of every leaf, which was illumined by the sun, was covered with a viscid juice, which tasted as sweet as diluted honey. From many of these leaves large drops hung from the point, and during that day and the following one much of this honey dropped down so as to moisten the gravel walk beneath the branches of every tree, and seemed more fluid as the sunshine became warmer; and the
leaves,

leaves, which were concealed from the sun, appeared to have less of the honey-dew, and some of them none of it.

How long this honey-dew had continued before I observed it, I cannot tell, but probably many days, as the weather was then, and had been uncommonly dry and warm, and shining; and after two or three days, when the weather changed, the morbid exudation, if such it was, or the excrementitious deposition of this viscid honey, became checked and gradually disappeared.

Beneath every leaf of this extensive hedge of filberts I discerned fifty or a hundred aphises of all sizes, and many of them had wings; but I could not perceive, that any of them had been on the upper surfaces of the leaves, where the honey only existed; nor were any bees, or butterflies, or ants, about these leaves; on which they must have adhered, if they had settled; which possibly they were aware of, as a hive of bees was at no great distance.

M. Duhamel observed a similar sweet juice drop in such quantity from willows by the side of a river in very hot and dry weather, that children were busy in catching or gathering it, and that it tasted like manna, but was more agreeable. He also mentions its dropping from nut-trees. *Physique des arbres*, Vol. I. p. 150. M. Reneaume, in the *Memoires* of the *Acad  m. des Sciences*, observed a similar exudation from the maple, and sycamore; and adds, 1. That it was unctuous and sweet. 2. That it was in the greatest quantity on the leaves exposed to the sun, which appeared wet on their upper surfaces; and that it was not seen before sun-rise. 3. That bees collected it as anxiously as common honey. 4. And that some leaves died, whose discharge was very great. 5. That it existed in a very dry and hot season. But neither of these philosophers speak of its being attended by the aphise.

The aphise this year was uncommonly numerous, the leaves of the peach and nectarine trees were half of them destroyed by this pernicious insect, and became blistered and curled I suppose by their punctures;

tures; which were made some weeks earlier in the year, and by an aphid without wings, and differing somewhat in their shape, but without any appearance of honey-dew on those trees. But I could not discover any punctures or other disease of the leaves of these nut-trees, and therefore doubt whether these insects, though so numerous on the under surface of every leaf, could be the cause of the morbid exudation, if such it was, on their upper surfaces; and the more as I could not distinguish, that they preyed upon the honey thus produced; and I afterwards observed that they continued in immense numbers under every leaf, when the weather became cooler, and moister, and the honey-dew ceased to be visible. But after a few weeks I observed the upper surface of every leaf became covered with a black powder like soot; whether this was a new material, or remained after the exhalation of the honey-dew, I did not determine by experiment. But if both the honey-dew and this subsequent black powder on the upper surfaces of the leaves, were the excrement of the aphid on the under surfaces of the leaves over the former, or owing to an exudation from the tree, must be determined by further observations.

But as a second period of sap-flow is believed to exist about mid-summer, or a deposition of vegetable nutriment for the new buds, as described in Sect. III. 2. 8. there is reason to suspect, that the honey-dew is owing to the inverted action of the external lymphatics occasioned by the debility induced by the continued heat, and perhaps to the moisture of situation. Whence the nutritive fluid is thrown upon the external habit instead of being applied to nourish the new buds, or to be laid up as a reservoir for their use. And that if it be voided by the aphid, it is owing to their puncturing the sap-vessels with the fine proboscis, which they possess, at this season only, or in a distempered state of the tree, and drinking more of it than they are able to digest. For a further history of this insect see No. 3. 2. of this Section.

8. *Exfudatio miliaris*, miliary sweat, appears to be produced by too great and continued heat, as it exists on vines in hot-houses, which are kept too warm, or too close in respect to their ventilation.

This secretion has not the sweet taste like that of the honey-dew, but consists of mucilage; which, as the watery part evaporates by heat, remains on the plant in very small round hard globules, like millet seeds, whence their name. I once witnessed a very similar appearance of minute hard round globules on the skin in a miliary fever, which easily were rubbed off with the finger; and were probably occasioned, as in this vegetable disease, by too great heat, and the exclusion of air, as described in *Zoonomia*, Vol. II. Class 2. 1. 3. 12.

In the evaporation of perspirable matter, which in its diseased state may be more mucilaginous than natural, in confined bed-rooms or hot-houses, I suppose, the aqueous part only is exhaled, and the mucilaginous part remains in the form of a globule; in the same manner as *stalactites* are formed on the roofs of caverns from a solution of calcareous earth in water, simply by the evaporation of the water.

9. *Fluxus umbilicalis*, sap-flow, this occurs, when the alburnum or sap-wood of trees is wounded in the vernal months, as in birch and maple, described in Sect. III. 2. 2. and consists of a saccharine and mucilaginous fluid similar to the honey-dew, or *suffusio melilita*; and is often very troublesome, when vines in hot-houses are pruned too late in the season, as the whole branch is liable to bleed to death, owing thus to the loss of the sap-juice, which ought to be employed in nourishing the young buds, and expanding their leaves.

When some perennial plants have risen but a certain height from the ground, if their stems are much wounded, or cut off, the roots are liable to bleed to death from this discharge of the umbilical fluid, or sap-juice, which ought to have nourished and expanded the new buds and foliage; as may be seen in cutting down the *heracleum spondylium*, cow parsnep, in April; and on this account it has been

recommended to mow down thistles, and other weeds, which are troublesome from their numerous increase, early in the spring; as many of them will then die, and the rest be much weakened by the sap-flow, which attends their wounds at that season.

In respect to trees another period of sap-flow is said to exist, when the new buds are forming after Midsummer, as spoken of in Sect. III. 2. 8. Whence wounds at this season also must be injurious; where this loss of sap-juice occurs in hot-houses various applications have been recommended by gardeners. I suspect that a bit of sponge bound upon the end of the cut branch, or on the wound, by means of some elastic bandage, must be the most certain application; or a wire twisted round the end of the branch cut off, so tightly as to strangulate the whole circulation of juices, and consequently destroy the part above the ligature.

10. *Secretio gummofa*, gum secretion, a morbid production of gum, which differs from the sap-juice above described, as it contains no saccharine quality, though like the former it exudes from the wounded alburnum of deciduous trees; whether the wound be originally caused by internal disease, or by external violence, as mentioned in the gangrene of the bark above described.

Where this happens to cherry-trees, *prunus cerasus*, a gum exudes like gum arabic; which in dry weather hardens, as it adheres, and thus prevents the further discharge of this nutritive material; otherwise the tree weeps away its life, perishing from deficient nourishment. In similar manner a resin is emitted from the injuries or wounds of pine-trees, and some other evergreens, with great injury to the growth, or the destruction of the tree.

This exudation of the gum or resin of trees, as it happens chiefly in summer, is probably a part of nutritious fluid designed for the new buds, which in most deciduous trees are formed about this time, and should be prevented from continuing to flow by binding on the part, previously made smooth by a knife, a metallic plate, as of the lead

in.

in which tea is wrapped, so as to prevent rain or dew drops from dissolving the indurated gum. A bit of sponge, or of soft leather, or of Indian rubber, caoutchouc, might be bound on under the lead, till the wound is healed. Might not a strong solution of green vitriol in water, or some ink, if applied to the extremities of these bleeding vessels, stimulate them into contraction, and prevent the further effusion of gum?

Another method might be worth trial, which is mentioned in Sect. XVII. 3. 10. A piece of bark from a similar tree of inferior value might be cut out, so as nicely to fit the wounded part, after its edges were nicely smoothed, and might be tied on by a proper bandage, as the lifting cut from the edges of cloth, or flannel, so that its elasticity might secure a perpetual pressure without injury.

II. DISEASES FROM EXTERNAL ELEMENTS.

1. In climates liable to incessant rains or perpetual drought for a length of time many diseases of vegetables must originate from the excess of moisture, or to the want of it; which are not very frequent in this country. In moist seasons the leaf-buds of plants, as of grass and corn, as well as of trees and perennial vegetables, grow too luxuriantly; and the flowers and consequent fruits or seeds are later, and contain more aqueous, and less mucilaginous and saccharine matter.

On the contrary, in dry seasons the leaf-buds are less vigorous, and therefore in less quantity, as the crops of hay, and the quantity of straw; but the fruits and seeds ripen earlier, and are of more grateful flavour, and more nutritious.

2. The effect of heat on vegetation is spoken of in Sect. XIII. 2. 2. The excess of that element is seldom much injurious to the vegetation of this country, unless it may contribute to increase the dryness of the soil, when there is a scarcity of moisture. But the de-

fect of the element of heat, or in common language excess of cold, is frequently destructive to the early shoots of the ash, fraxinus, and to the early blossoms of many fruit-trees, as apples, pears, apricots; as these are either more succulent, or have less irritability, or more sensibility; on both which accounts they are more liable to be diseased by cold.

The blights occasioned by frost generally happen in the spring, when cold nights succeed to warm sunny days, as the living power of the plant has then been previously exhausted by the stimulus of heat, and is therefore less capable of being excited into the actions, which are necessary to vegetable life, by the greatly diminished stimulus of a freezing atmosphere.

In some northern climates, where the long sunny days succeed the dissolving of the snows, as in Denmark and in Russia, the gardeners are said to shelter their wall-trees from the meridian sun in the vernal months; which preserves them from the cold of the succeeding night; and by preventing them from flowering too early avoids the danger of the vernal frosts.

The destruction of the more succulent parts of vegetables, as their early shoots, and that especially when exposed to frosty nights, was spoken of in Sect. XIII. 2. 2. and can only be counteracted by covering them from the descending dews or rime by the coping-stones of a wall, or mats of straw.

3. The blasts occasioned by lightning are more frequent, I believe, than is usually supposed; as I am informed by those, who purchase extensive woods, that very many trees on being sawed through are found cracked, and much injured by lightning. I had last year a standard apple-tree, and a tall apricot-tree, in full leaf blasted at the same time by lightning, as was believed. They both lost all their leaves; the apple-tree nevertheless put out a new foliage, and recovered, and bore fruit this year; but the apricot, which was nailed to a high wall, never shewed any returning life.

Mr.

Mr. Tull ascribes one injury to the health of wheat plants, and frequently their death, to lightning; the effects whereof, he says, may be observed by the blackish parts or patches visible in a field of wheat, especially in those years which have more thunder-storms than usual, and adds that against this there is no remedy.

The erection of frequent metallic points could alone secure a garden or field from this misfortune; which probably occurs more frequently on damp situations, than on dry ones; as mentioned in the account of Fairy Rings in Botanic Garden, Vol. I. note XIII.

The manner in which lightning destroys the life of vegetables may be similar to that, in which it destroys animal life; which is I suppose by its great stimulus exhausting the sensorial power in the violent action it occasions, and thus producing total inirritability to the common stimuli, which ought to excite the vital actions of the system; similar to which, though with less expedition, seems to be the effect of some poisons on the animal system, as the distilled water of lauro-cerasus, a solution of arsenic, the contagious matter of fevers, and even a common emetic; all which by their strong stimulus seem almost instantaneously to render the stomach, and other parts of the system, nearly or entirely inirritable, or disobedient to their natural stimuli.

It may also affect vegetables in another way similar to that, which probably also happens, when their young succulent shoots are frozen; that is, by bursting their vessels, as it passes through them, by its expansive power; as happens to the large branches of some trees, and to stone-buildings, and other bad conductors of electricity, when they are struck with lightning.

The expansive power of electricity is not only shewn by trees and towers being rent by lightning, but by the sound, which succeeds the passage of it through air; since a vacuum, or nearly a vacuum, in respect to air must previously be made by the presence of the electric fluid; and the sides of this vacuum rushing together, when the

stream

stream has passed, occasions the consequent vibrations of the air, which constitute sound, whether in the audible spark of electricity, or the tremendous crash of thunder. See Sect. XIII. 3.

4. The element of light, as well as that of heat, is necessary to vegetation. In this climate they both seem in general to be injurious only by their defect, and seldom by their excess. But as light acts as a stimulus on the more irritative or sensitive parts of plants, which appears by the expansion of many flowers, and of some leaves, when the sun shines on them; and by the nutation of the whole flower, as of the sun-flower, *helianthus*; and by the bending of the summits of all plants confined in houses towards the light; there may be diseases owing to the excess of this stimulus, which have not been attended to; to prevent which the flowers of *tragapogon falsafi*, and of other plants, close about noon. Other unobserved diseases may be owing to a defect of the stimulus of light; as a *mimosa*, sensitive plant, which I had confined in a dark room, did not open its foliage, though late in the day, till many minutes after it was exposed to the light.

The excess of light has not been observed to be attended by vegetable diseases in these more northern latitudes; but the disease produced by the deficiency of it, which is termed etiolation, or blanching, has been successfully used to render some vegetable leaves and stalks esculent by depriving them of much of their acrimony, and of their cohesion, as well as of their colour; as is seen in the blanching of celery, apium; endive, cichorium; cinara, cardoon; sea-cale, *crambe*.

The following method of the growth and etiolation of sea-cale is transcribed from the letter of a friend; to which should be added, that the young heads of this vegetable without blanching are equal or superior to most kinds of brocoli, *brassica*. "Sea-cale seed should be sowed the latter end of March or beginning of April in drills, and then earthed up. In autumn it should be transplanted into high beds, one row of roots in a bed, about a foot asunder, and in the
winter

winter it should be covered up. It must be kept dry, that is, the beds made in the driest ground; it is not fit to be eaten till the third year after it is sowed. The year before it is eaten it must be covered up in the beginning of winter, first with stable dung, which may be kept from pressing on it by a few sticks placed like a cone over each root; then with long litter two or three feet high; the higher the better, because the more it is forced, the earlier it is fit to be gathered, and the whiter it will be. It is to be gathered about the beginning of January, and so on till May, one bed being kept under another. It should be boiled and sent up on toast like asparagus, and is an excellent vegetable, and at an early season."

5. The earth, on which vegetables insert their roots, sometimes presents noxious materials to their absorbent system, as the acidity of some clays; into which when the roots of some fruit trees penetrate, they are said to lose their health, as mentioned in Sect. II. 9. by the death or decay of their root-fibres.

Pure siliceous sands also prevent vegetation from their containing no carbonaceous matter, and by their so readily permitting the dews and rains to exhale from them, especially in hotter climates, where they constitute a moving surface unfriendly to all organized life.

6. There are also noxious exhalations diffused in the atmosphere in the neighbourhood of some manufactories; which are said to injure the growth or destroy the life of vegetables; as the smoke from the furnaces, in which lead is smelted from the ore, from potteries, and from lime-kilns; to which may be added the marine salt, or marine acid, which abounds in the too great vicinity of the sea.

To these belong the experiments of Dr. Peschier of Geneva, who immersed several plants in vapours of nitrous acid, of volatile alkali, and of ether, to the great injury or death of the plants. *Journal de Physique par Delametherie*, T. ii. p. 345.

7. Unwholesome or poisonous materials may be applied to vegetables so as to disease or destroy them; as their absorbent systems like those

those of animals are liable to imbibe many noxious materials, as mentioned in Sect. II. 8. A slight solution of arsenic, sprinkled on a peach-tree in the spring, destroyed the branches which received it. A solution of liver of sulphur was equally fatal to the branches of a nectarine-tree, and also oil of turpentine.

Mr. Von Uslar affirms, that watering plants with a due quantity of oxygenated muriatic acid will increase their irritability; and if carried beyond a certain degree will injure or destroy the vegetable by giving it too much oxygen; which is known in due quantity to be a salutary material, and the most necessary of all others to vegetable as well as to animal life.

8. There are materials called condiments, which are believed to possess stimulus without nutriment in respect to animal bodies, as spice, salt, bitters, as the hop, and probably opium and vinous spirit. These when taken into the stomach increase its activity, and render the animal for a time fat, and even strong; but as all increase of stimulus, beyond what is natural, is followed by debility; after a time the animal becomes weak, and emaciated; and enervated in mind as well as body; as is uniformly seen in those who are addicted to the use of much beer and wine, or of opium; and in a less degree where spice, or salt, or bitters, are taken in too large quantity.

What then shall we say to the use of common salt in agriculture? as it is a stimulus, which possesses no nourishment, but may incite the vegetable absorbent vessels into greater action; it may in a certain quantity increase their growth by their taking up more nutriment in a given time, and performing their circulations and secretions with greater energy. In a greater quantity its stimulus may be so great as to act as an immediate poison on vegetables, and destroy the motions of the vessels by exhausting their irritability.

After a time I suspect vegetables will always be liable to disease from this stimulating innutritive material; and that though it may increase the early growth of the plant, it will injure its flowering or feed-

feed-bearing ; and that hence, if it be used at all, it should be a little before the time, that the plant would acquire that part of its growth, which is wanted. Thus if the herb or young stem only be wanted, as in spinage, mercury, asparagus, apply salt early ; if the flower be wanted, as in brocoli and artichoke, or in tulip or hyacinth, moisten them with a slight solution of salt, when the flower-bud is formed. When the fruit or seed is wanted, as in melons or cucumbers, or peas and beans, apply the solution of salt still later, and at all times with rather a parsimonious hand. See Sect. X. 7. 4.

Similar to this, where animals diseased with superabundancy of fat are required, it is customary, I am told, to feed poultry for the London markets by mixing gin and even opium with their food, and to keep them in the dark ; but they must be killed as soon as their corpulency is formed, or they soon become weak, and emaciated like human drunkards. And in some countries, as in Languedoc in France, the livers of geese and ducks are required to be enlarged and diseased ; as they are reckoned a dainty by modern epicures, as well as by the ancient ones, who speak of the tumidum jecur anseris ; and for this purpose the animals are kept in the dark, and crammed with more than their natural quantity of nutriment ; but are said to become lean, and to die, if not killed as soon as this disease is produced.

It is nevertheless to be observed, that sea-salt as well as other stimulating condiments may be advantageously used as medicines, though injurious as common food. Thus it is asserted by Baron Schulz in the communications to the board of Agriculture, Vol. I. Part III. and IV. p. 318, that it destroys the fasciola hepatica, or flewk-worm in sheep. Some have recommended one ounce of salt to be given every day dissolved in water, but it is probable, it might be used with greater advantage, if hay was moistened with the solution, which would thus at the same time supply them with better nourish-

ment than generally falls to the lot of these diseased sheep, on supposition that they would eat it.

The rot of sheep, I suspect, arises from the inactivity of the absorbent vessels of the liver of that animal; whence the bile is too dilute, especially in moist seasons; whence the flewk-worm, as I have seen in the shambles, inhabits the common bile-duct, and at length erodes the liver, causing ulcers; which from the sympathy of the lungs with the liver occasions a cough, and a hectic fever from the absorption of the matter. Hence the salt by its additional stimulus may render the bile less dilute by promoting a greater absorption of its aqueous parts, as well as a greater secretion of it; which however I suspect would be much more efficacious, if about sixty grains of iron-filings made into a ball with flour was given every morning for a week along with the salt, as further explained in *Zoonomia*, Part III. Art. 4. 2. 6. 4.

Since writing the above account of common salt as a condiment, and the probable consequences attending the use of it, I have met with some experiments published by Lord Kaimes in his *Gentleman Farmer*, which seem much to confirm the preceding account. He watered some Jerusalem artichokes, *helianthus tuberosus*, which were planted in separate pots, with a solution of fixed vegetable alkali, others with volatile alkali, others with weak lime water, others with strong lime water, others with putrid urine, and lastly others with water impregnated with putrid animal and vegetable substances, I suppose as they exist in a dunghill. All these saline solutions at first encouraged the growth of the respective plants, so as much to surpass those in the pot, which was moistened only with common water, as a standard to compare the others to; but by additional quantities of the solutions, they all, except the last, gradually lost their vigour, and perished in the end, as I suppose, by the excess of stimulus.

There

There is also an experiment in the works of Mr. Anderson, which seems to shew, that common salt possesses no nutritive quality adapted to vegetable growth; and that in some soils, or to some vegetables, it would seem not even to act as a stimulus or condiment. He marked out a circle of six feet diameter in the middle of a grass field, which he distinguished by driving a stake in the centre; on this circle he strewed common salt, so as to lie nearly an inch thick on the ground. The grass sprung up in this circle in the same manner as in the other parts of the ground, and the place could only be distinguished by the stake, though it was left there for some years. *Encycl. Britan. Art. Agriculture.* See Sect. X. 7. 5. of this work. This experiment is worthy to be repeated, lest there might have been some mistake attending it; as so many authors have given experiments with contrary results; and as some other neutral salts were shewn to promote vegetation in the experiments of Dr. Home.

9. Some diseases from external violence have been already mentioned in this Section, in which the injury is a remote rather than a proximate cause of the disease, as in the canker sometimes, and the sap-flow, and gum-secretion. But some other diseases from external violence have been purposely produced, as well as that of etiolation, and turned to advantage; as the bunches of grapes, which have acquired their full size, are said to ripen sooner, if the stalk of the bunch be cut half through. Tournefort says, that the figs in Provence and about Paris ripen sooner, if the buds be wounded with a straw dipped in olive-oil. And lastly, the figs in the island of Malta are made to ripen sooner by caprification; as spoken of in *Botanic Garden*, Vol. II, note on *Caprificus*. And it may daily be remarked, that those apples and plums ripen sooner, which have been wounded by insects; and that pears will ripen considerably sooner, if they be immaturesly plucked from the tree, which must be esteemed injurious to the life of the pear; and as the conversion of austere acid juices of fruit into sugar in the process of ripening may be in part che-

mical, it may proceed more hastily, when the life of the fruit is impaired or destroyed; as seems to occur in the drying of germinated barley, and in baking pears, as well as in bruising apples for the purpose of making cyder; which last effect might probably be much improved by the addition of warmth.

III. DISEASES OCCASIONED BY INSECTS.

1. Among the diseases of plants Linneus adds in his *Philosophia Botanica* the nests of those insects, which deposit their eggs in plants; whence a variety of excrescences. These are, 1. The galls of oak, of ground-ivy, cistus, trembling poplar, willow, and hawk-weed. 2. Bedeguar of roses, or briar-balls. 3. Follicles of pistachia, and black poplar. 4. Contortions of cerastium, chick-weed, veronica, speedwell, and lotus. 5. Scales of firs, willows, and roses.

He then adds, that the duplicature and proliferation of flowers is often occasioned by insects, as common chamomile, *matricaria*, is thus made *proliferus*; and that *carduus caule crispo* bears larger florets, with the pistils growing into leaves, by the wounds of insects.

It must be observed, that these excrescences on the leaves of some plants, or mutation of their manner of growth, are not always the consequence of a simple wound or puncture of the insects, but of the deposition of their eggs, or young offspring; which afterwards continue to stimulate the growing plant into unnatural motions, and consequently into unnatural growth; like the inflammation and consequent new granulations of flesh in the wounds of animal bodies; which, if the skin is prevented from spreading over them, will rise into large substances of fungous flesh; or beneath the skin, where it is loose, as in wens.

Many flowers are destroyed or rendered unprolific by the depredation of insects, as rose-buds by the cynips; and I remember observing one dry summer, that every blossom of a large quince tree

was

was pierced by a fly, and rendered unprolific before the blossoms had opened. I have also seen the hood of the aconite, so replete with an acrid juice, pierced by insects to plunder it of its honey.

2. The curling of the leaves of nectarine, and peach, and cherry-trees, with the cells or bladders on their surfaces, are formed in consequence of the wounds inflicted by the aphid; in the same manner as the galls and bedeguars on the oak and sweet-briar by other insects, but without their nidification or the deposition of their eggs; though from the sudden and general appearance of these injuries they have been ascribed to blights from inclement weather.

Some observers have believed nevertheless, that these affected leaves were previously out of health; which occasioned them to supply a proper situation for those insects, which molest them; as I have frequently observed, that snails or slugs eat those leaves, which have been plucked from cucumber plants, and are beginning to wither; in preference to those, which are growing in perfect health.

Mr. Lawrence relates, that in June the leaves of some of his wall-pear-trees were much injured by a hail-storm, which leaves were afterwards blighted, and become full of tumours from insects; and the pears, which were then as large as walnuts, all perished. On this Mr. Bradley remarks, that insects generally lay their eggs on the dead or putrefying parts both of vegetable and animal bodies; and adds a conjecture, that the parent insects may circulate in the juices of the plant, which however is not probable, as though microscopic animals have been discovered in the stagnating juices of animal bodies, as in the pustules of the itch, and in the fæces in the dysentery; and even in the semen, which may have stagnated in the vesiculæ feminales; yet no such animalculæ have, I believe, ever been detected in recent blood, or any recent secretions from it.

A predilection for some withered leaves appears also in larger animals as well as in insects; cows will eat young thistles, a few hours after they are cut down, as their prickles become flaccid; and horses refuse

refuse the young shoots of yew-trees, as they grow; but will eat them when they are cut off, and begin to wither; and on that account lose a part of their acrimony; though there is still often sufficient poison within them to destroy the animal. And it is even probable, that when the leaves of yew are withered to a greater degree, their poisonous acrimony becomes so far destroyed, that they cease to be deleterious to horses; so that in Hesse in Germany it is customary in the winter to crop the young shoots of yew-trees, and mixing them with other provender to give them as common food to horses. See Anderson on Agriculture, Vol. III. p. 590.

On this account if wall-trees are frequently watered by an engine, so as to moisten their leaves or branches as well as the ground at their roots on the dry days in spring, by which they will be kept in vigorous growth, I was told, that they would totally or nearly escape the depredations of insects; but I found by an experiment well conducted on three trees, that this management had no effect; and I also observed in the spring and summer of this year, 1798, which seems to have much favoured the production of the aphis, that they attacked the most healthy leaves of peach and nectarine trees, as well as the others; and that plums, cherries, black currants, and many other trees suffered by their depredations, though previously in perfect vigour. And lastly, that on repeatedly having washed off many thousands of aphises from peach and nectarine leaves by a strong stream from a forcible water-engine, that they evidently crawled again up the stems of the trees, or on the wall to which they were nailed, as in another day the lowermost branches were thus more infested with them than the upper ones.

The history of the aphis, puceron, or vine-fretter, is so curious, the destruction it commits on the foliage of the peach and nectarine is in dry summers so irresistible, and its existence on other trees so extensive, that it demands our particular attention. See No. 1. 7. of this Section. From the observations of Swammerden, Bonnet, Dr. Richardson,

Richardson, and of other philosophers, this extraordinary insect rises in the spring from eggs, which are said to be attached by the parent aphids to the twigs of trees in the autumn, and are believed to produce not a larva or caterpillar, but a progeny similar to the parent; every one of which produces in about ten days not an egg, but another living progeny to the ninth generation; without being connected amatorially with each other. The ninth generation produces males and females, some of both kinds with wings, and others without them; and this tenth generation from those, which were hatched from eggs, become amatorially connected, and produce eggs; which are laid on the new twigs of various trees for the next year's progeny to be hatched by the vernal sun. *Philos. Transact. Vol. LXI. p. 182.*

In this uncommon circumstance the eggs of the aphids resemble the seeds of plants; which first produce some successive generations of leaf-buds, which are a viviparous progeny, before they again produce seeds, which are their oviparous progeny, as mentioned in Sect. IX. 3. 1. of this work. Nor is this to be ascribed to what has been termed equivocal generation, or to an impregnation of nine fetuses enclosed within each other, as some have supposed. But this central production of the viviparous progeny of the aphids seems to resemble the lateral production of a viviparous progeny from the polypus, which in time detach themselves from their parents; like the buds of the polygonum viviparum, or the bulbs of the magical onion, *allium magicum*; which are produced from the flower-cup instead of seeds, and in time detach themselves, and fall on the ground. So that these aphides are not, I suppose, to be esteemed fecundated females, but prolific males, as explained in *Zoonomia, Vol. I. Sect. 39. on generation.*

This double mode of reproduction, so exactly resembling the buds and seeds of trees, accounts for the wonderful increase of this insect; which according to Dr. Richardson consists of ten generations, and of fifty at an average in each generation; so that the sum of fifty multiplied

multiplied by fifty, and that product again multiplied by fifty nine times, would give the product of one egg only in countless millions; to which must be added the innumerable eggs laid by the tenth generation for the renovation of their progeny in the ensuing spring.

Their punctures of the leaves of peach and nectarine trees in the vernal months, and of cherry, plum, and currant trees in the summer, produce a swelling and elevation of the cuticle of the leaf on its upper side, and a consequent curling of it with its upper surface outwards, which terminates in a destruction of it to the great injury of the tree, and frequently to the death of it; while the leaves of the nut-trees, mentioned above, in No. 1. 7. of this Section, appeared to be but little injured by them, though fifty or a hundred of these insects were seen under every leaf about Midsummer, both before and after their affusion with the honey-dew.

From Dr. Richardson's account the aphises on the rose-tree appeared in February, when the weather happened to be warm, from small black oval eggs; which were deposited on the last year's shoots in autumn; and that, when the weather became colder, great numbers of them perished, by which circumstance the rose-trees are in some years almost freed from them.

They came to their full growth before April, and after having twice cast off their exuviae, every one of them produced about fifty young ones; all of which came into the world backwards, and adhered sometime to the vent of the parent by their mouths or forepart; as shewn in a magnified state at fig. 2. plate IX; and were at length set down on some tender shoots of the plant, and came to maturity in about ten days, casting off their coats two, three, or four times.

The ninth generation in October consisted of males as well as females, which were seen to cohabit; and the eggs produced by their intercourse, he asserts, were deposited generally near the new buds, or on other parts of the twigs of the trees, which they possessed.

These were at first green, but in a few days became brown, and by degrees quite black. They were of regular oval figures about one tenth of an inch in length, and about half as broad, and adhered firmly by means of something glutinous, and resisted the severity of the winter.

Other insects, which are produced from eggs, and become winged butterflies or moths, live for some time in the intermediate state of caterpillars or larvæ. During this state of their existence they feed on the leaves, on which they are hatched; or on fruits or kernels; but after they have acquired wings and organs of reproduction, some of them take no food, as the silkworm; and others live only upon honey, as bees, and moths, and butterflies. Now the aphids, I suppose, has no intermediate state between the egg and the fly, and therefore makes no holes in the leaves by eating them; or if any of them previously exist in a caterpillar, or larva state, it can be only those which are produced from eggs in the early spring, which is worthy of future attention.

Whence I suppose, that this fly lives not by consuming the foliage of the plants, which it inhabits; but by piercing the pulmonary vessels in their natural state, or the lymphatic vessels of the leaf in their retrograde state, by a fine tube or proboscis, which it possesses, and which it may be seen by a common lens perpetually to employ, as shewn under its chin in the magnified insect at figure first of plate IX. For the sap-juice or vegetable chyle is brought from the radicles of each leaf-bud, and propelled up the long caudex to the pulmonary artery of the leaf, where it becomes oxygenated, and converted into vegetable blood. And may thus be extracted by the tubes of these insects before its sanguification.

Perhaps those aphides, which were from eggs, might eat some part of the peach leaves during their larva state, if such exists, and occasion them to curl up. While those, which were a viviparous progeny, might only pierce the sap-vessels, or blood vessels, and thus not ap-

parently injure the leaves; as on the nut-trees, where perhaps they were not hatched from eggs, but might have come thither in their winged state, and have then produced their innumerable viviparous offspring; as on the nut-trees above mentioned I could not discern the eggs, from which they were hatched, and a few larger aphises with wings appeared early in the season amongst the smaller ones without wings.

We may finally conjecture on this interesting subject, first, that the aphises produced from eggs early in the spring may have a larva or caterpillar state, and that during that state they may feed on the young leaves of peaches, nectarines, plums, and cherries, and thus occasion them to curl and die. 2. That those, which are not from eggs, have no larva state, and only puncture the larger chyle vessels of the young twigs, or the pulmonary arteries of the leaves, which receive the vegetable sap-juice from the roots, and thus that they suck it up, and live on it, before it is converted into blood, as moths, butterflies, and bees, live on honey in their winged state, though on other parts of vegetables, as on their leaves, or anther-dust, in their larva state; and that these punctures are attended with no visible injury to the leaf. 3. That for a week or two about Midsummer, when the umbilical vessels of the new buds convey the sap-juice to them, or to the reservoirs of nutriment preparing for them, that the aphises by piercing these vessels, or the pulmonary arteries of the leaves, acquire so large a quantity of this saccharine material, that it passes through them almost unchanged, falling on the leaves and ground beneath them, and produces what is called the honey-dew; but that this happens only for a short season, as a week or two about Midsummer, during the production of the new buds. And lastly, that the black powdery material on the upper surface of the leaves of the nut-trees and plum-trees, and of the shrubs which grow beneath them, is an excrement from the aphises, which hang on the under surfaces of the leaves above them, like the black bitter powder in the
nut-

nut-shell; which is the excrement of the curculio, which has eaten the sweet kernel.

Secondly, having last year written the above, I have had another opportunity of attending to the aphid during the summer of 1799, and shall add the further remarks, which I have been able to make on this most curious and important animal, which may in process of time destroy the vegetable world.

As the month of June was again in this summer very dry, though not very warm, the aphid was propagated in immense numbers on a great variety of trees, shrubs, and herbaceous plants. The row of nut-trees mentioned in No. 1. 7. of this Section was infested with a greater number of them this year than in the preceding one; yet during the season about Midsummer there was so little honey-dew this year, that it might have escaped observation, if it had not been particularly attended to; yet what did appear was only on the upper surfaces of those leaves, which had other leaves impending over them crowded with aphides; whence I had no doubt, but that it was voided by the millions of aphides, which adhered on the under surfaces of those superior leaves with their backs downwards.

On examining them with a strong magnifier I could frequently perceive them insert their proboscis or trunk into the vessels of the inferior surface of the leaf; and particularly observed, that when they were not moving from place to place, that they generally stood with their heads towards the foot-stalk of the leaf of nut-trees, or towards the base of the twigs of plum-trees, which circumstance I shewed to many of my friends.

Both before and after the existence of the honey-dew a black material, which was sometimes moist and sometimes dry, appeared on the upper surfaces of those leaves only, which had other leaves crowded with aphides over them, and even on the upper surface of the leaves of some herbaceous plants, which grew under these nut-trees,

and also on others, which grew under plum-trees, which were much infested with an aphid of a greener colour.

To prove beyond possibility of error that this black matter was deposited on the leaves below by the aphides, which were walking with their heads downwards on those above, I sewed slightly with a needle and thread under several leaves a piece of writing paper about the size of the leaf; and observed on the next day that many black marks were distinguishable on the paper.

On plum-trees and on many herbaceous plants innumerable aphides were seen on the upper tender part of the upright shoots, adhering with their heads downwards; and on the hanging shoots with their heads upwards; and inserting their proboscis into the vessels, I suppose, which contained the ascending sap-juice. But on the nut-trees the most tender or uppermost parts of the young shoots were covered with very numerous bristles, which appeared to be an armour purposely produced to defend them from these destructive insects, and hence they were principally found on the under surfaces of the leaves.

As the chyle of animals is mixed with the venous blood, and is immediately projected by the force of the heart into the pulmonary artery, at the extremities of which it is principally converted into blood by its exposure to the air; so in the vegetable system the sap-juice must be mixed with the returning venous blood, and carried forwards to the extremities of the pulmonary artery of the leaf, before it is converted into vegetable blood. These pulmonary arteries pass along the under surfaces of leaves, as the upper surfaces of them are covered by the fine terminations of them on an air-membrane for the purpose of respiration; hence on these under surfaces of leaves the aphides adhere, and pierce the branches of the pulmonary arteries with their proboscis standing with their heads towards the stalk of the leaf, that they may thus meet the streams of chyle or sap-juice yet unchanged
into

into blood; which accounts both for their existing in all kinds of weather on the inferior side of the leaves, and for their standing with their heads towards the foot-stalks of them. Thus on an upright twig of a plum-tree I this day observed a number of aphises adhere with their heads downwards with their proboscises inserted into the tender stem, and so near to each other, that the tail part of the lower ones extended one third of their length over the head part of those above them, and gave somewhat the appearance of scales; while on the hanging twigs they adhered with their heads upwards, still intent to meet the streams of sap-juice in the ascending chyle vessels, or in the pulmonary arteries.

Dr. Bradley and others observe, that about Midsummer there appears to be a pause in vegetation, and that at this time the new buds are generated; and Duhamel and others found, that the bark of several trees became at this time as easily to be separated from the alburnum as in the spring; as is related in Sect. III. 2. 8. of this work. At this time therefore there exists a new flow of sap-juice to supply present nutriment, or to furnish a reservoir of future nutriment to the newly generated or expected embryo, either before or after its vivification, or its impregnation, if such a process may be supposed to occur in the production of buds.

At this time then, when there exists a summer-flow of sap-juice, this pernicious insect in uncounted millions pierces the sap-vessels round the new shoots, or the pulmonary arteries beneath the leaves; and thus drinks the vegetable chyle, or sap-juice, with such avidity, as to part with much of it again almost unchanged. This I now believe with Sauvage to be the origin of one kind of honey-dew certainly; and if another kind of honey-dew exists, as he mentions, where there are no aphises, I suspect, as observed in No. 1. 7. of this Section, that it must arise from the inverted action of the lymphatic vessels of the leaf, at the time of the increased quantity of sap-juice

about Midsummer ; but have not had an opportunity to ascertain these facts.

Thirdly. There appears to be a power impressed on organized bodies by the great author of all things, by which they not only increase in size and strength from their embryon state to their maturity, and occasionally cure their accidental diseases, and repair their accidental injuries, but also a power of producing armour to prevent those more violent injuries, which would otherwise destroy them. Of this last kind are the poisonous juices of some plants, as of *atropa belladonna*, deadly nightshade, *hyoscyamus*, hen-bane, *cynoglossum*, hounds-tongue. Other plants are armed with thorns and prickles to prevent the depredation of animals, as *ilex*, holly, *cratægus*, hawthorn, *ribes grossularia*, gooseberry ; the leaves of which would be perpetually devoured but for this kind of protection. Other plants secrete a viscid juice to agglutinate the insects, which crawl up towards their fructification, as *silene*, catchfly, *drosera*, sun-dew ; and others by the contraction of their leaves or petals arrest or destroy the insects, which attack them, as *dionœa muscipula*, and *apocynum androsæmifolium*.

But how can vegetables protect the whole inferior surfaces of their leaves, and of their young rising stems from the innumerable progeny of the destructive aphis, which penetrates their chyle vessels and their arteries ; and which from their immense numbers may in process of time destroy the vegetable world. Many vegetables have not yet acquired any means of defence, and have therefore the first growth of their foliage much injured, or totally destroyed by this destructive insect, as the nectarine, and peach, and plum, and cherry-trees, in many parts of this country, as is every year seen and lamented.

Some vegetables have nevertheless already acquired an armour, which lessens, though it does not totally prevent, the injuries of this animal. This is most conspicuous on the stems and floral-leaves of
moss-

moss-roses, and on the young shoots and leaf-stalks of nut-trees. Both these are covered with thickset bristles, which terminate in globular heads, and not only prevent the aphid from surrounding them in such great numbers, and from piercing their vessels so easily, but also secrete from the gland, with which I suspect them to be terminated, a juice; which is inconvenient, or deleterious to the insect, which touches it.

Hence moss-roses appear to be less injured by the aphid, than other roses, which have less of this armour; and while on plum-trees, and on many herbaceous plants, they hang round the upright young shoots with their heads downwards, and insert their trunks, so as totally to conceal the rising shoot; yet on nut-trees, though they are seen in millions beneath the leaves on the unarmed parts, they never appear round the young shoots, nor on the large trunks of the vessels beneath the leaves, all which have acquired a panoply of bristles with glandular heads to them, like those round the moss-rose, but without the branching structure of the latter. While those plants, which are not infested with the legions of this self-productive animal, have probably acquired some material mixed with their sap-juice, or blood, which is poisonous to them; as those plants, which possess a milky or a yellow blood, as the spurge euphorbia, or the celandine chelidonium, or the fig-tree, ficus.

Nor is this more astonishing, than that the holly-trees should annually supply prickles only to their lower leaves, about six or eight feet from the ground; as high as the animals can reach them, which would prey upon them; but refuse the expence of putting forth prickles in their higher branches, which are saved by their situation, as I have repeatedly observed on the numerous holly-trees, which are the ornament of Needwood forest.

From hence I suspect, that another reason, why the leaves of nut-trees and of rose-trees are not curled up or blistered like those of nectarines, peaches, plums, and cherries, is because their foot-stalks,

and the larger branches of the pulmonary arteries, are defended by these bristles, which are perhaps only beginning to appear on the leaf-stalks of the plum, but which may increase in the progression of time; as all the works of nature may be approaching to greater perfection, as mentioned more at large in No. 2. of the last Section of this work.

Fourthly. The means of destroying an insect so extensively injurious not only to gardens and hot-houses, but to half the vegetable world, would be indeed a valuable discovery. If the eggs exist on the young buds, as Dr. Richardson affirms, some application to these, before they are hatched, which might dissolve their shells, as by very dilute marine acid injected on them; or by some adhesive material, which might inviscate them as soon as they are hatched, whether they appear first in their larva state, like minute caterpillars, or in the form of the parent aphis, as soap-suds injected on the twigs before the leaves begin to unfold; or perhaps by rubbing them with oil or glue by means of a sponge, or a painter's brush; but experiments alone can determine the effect of these applications, both on the insect and on the tree.

Lime water alone will not readily destroy the aphis, as I observed by immersing leaves with aphises on them; which crept up the leaves, and thus escaped. But if pot-ash, or fixed alkali, be mixed with lime, the solution becomes so caustic as to destroy many insects without injuring the foliage of trees, or the stems of wheat, if we may credit M. Socoloff, who in the transactions of an Academy at Petersburg, Vol.V. asserts, that he added three parts of quick-lime newly made to two parts of a saturated solution of fixed alkali in water; which poured on the ground destroyed the earth-worms, and sprinkled on the leaves of trees destroyed the caterpillars, but did not injure, or much injure the foliage of trees, or the leaves of wheat plants.

Tar water has lately been said to destroy flugs, white snails without

out shells, and might be worthy a trial by injecting it on trees at first with caution, lest it should injure them; as it is probably the vegetable acid chiefly, with a small portion of essential oil, which is dissolved, or mixed with the water, by agitation. See No. 3. 5. of this Section.

Previous to the pullulation of the buds, it is also believed to be of great service to water wall-trees with lime-water, or with soap-suds, or perhaps with the addition of some pot-ash to either of them to make a more caustic ley, such as is recommended for steeping seed-wheat; but this with caution, as I have known a solution of hepar sulphuris kill the branches of a tree, which were moistened with it, as well as the insects, which were upon it. Nor am I certain that this will answer the purpose from the observations I have heard from those, who have tried it.

The essential oils are all deleterious to certain insects, and hence their use in the vegetable economy, being produced in flowers or leaves to protect them from the depredations of their voracious enemies. One of the essential oils, that of turpentine, is recommended by M. de Thoffe for the purpose of destroying insects, which infect both vegetables and animals. Having observed that the trees were attacked by multitudes of small insects of different colours (*pucins* ou *pucerons*), which injured their young branches, he destroyed them all entirely in the following manner. He put into a bowl a few handfuls of earth, on which he poured a small quantity of oil of turpentine; he then beat the whole together with a spatula, pouring on it water, till it became of the consistence of soup; with this mixture he moistened the ends of the branches, and both the insects and their eggs were destroyed, and other insects kept aloof by the scent of the turpentine. He adds, that he destroyed the fleas of his puppies by once bathing them in warm water impregnated with oil of turpentine. *Mem. d'Agriculture, An. 1787, Printemp. p. 109.*

I sprinkled some oil of turpentine by means of a brush on some
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branches of a nectarine-tree, which was covered with the aphid; but it killed both the insect and the branches. A solution of arsenic much diluted did the same. Might not the scent of turpentine, or of tar, smeared on a fruit-wall deter the flies from approaching the trees to deposit their eggs? or might not arsenic mixed with honey be smeared on the wall, to which the trees are nailed, be likely to attract the aphid as well as other kinds of flying insects. But none of these should be smeared on the branches, lest it injure or destroy the tree. Perhaps if a few twigs smeared with turpentine, mixed with a little oil of turpentine to make it more fluid, and to increase its odour, were fixed in quince-trees, or in apple-trees, the flowers of which are liable to be destroyed by the eggs deposited in them by a small fly; they might be deterred from approaching the tree, as the great use of essential oils, which cause the fragrance of flowers, seems to be to deter insects from infesting their leaves, or preying upon their honey.

It is probable, that if infusions were made in hot water, or perhaps for a longer time in cold water, of those leaves which no insects devour; as of the walnut, juglans; lauro-cerasus, laurel; foxglove, digitalis; hen-bane, hyoscyamus; hounds-tongue, cynoglossum; rag-wort, fenecio jacobæa; or of tobacco, nicotiana; and many others; and were sprinkled on the curled leaves of wall-trees, or on the buds before they open, by a pump, or by a brush, or sponge; they might destroy the insects without injuring the trees, which might be determined by a few experiments.

The dust of tobacco is frequently spread on affected leaves, but not I believe with very encouraging success, owing perhaps to the powder not being very fine, or not soon enough applied. Some kinds of lime strewed on in powder might probably be too caustic, and destroy the leaf along with the insects; which also might be subjected to experiment. The powder of sulphur, or of tobacco, or of any of the poisonous leaves above mentioned, might be injected upon affected trees
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by a powder-puff, such as hair-dressers use, or the smoke of tobacco, or of any other of the poisonous leaves above mentioned, might be forcibly blown on them by an adapted pair of bellows, as the smoke of many of them may possess as poisonous a quality as that of tobacco; and even the steam of a decoction of others, as of lauro-cerasus, and walnut; the poison of the former of which is known to rise in distillation, might probably be used with effect; but this must depend on the greater or less fixity of their essential oils. The smoke or steam might be applied to wall-trees by previously suspending over them a large sheet of matting, or of linen, or of paper, or an old carpet; but may however be used with greater advantage in hot-houses, than in the open air.

Since the above was written I directed in the early spring of this year one nectarine-tree to be moistened with tar-water, and parts of the wall to be smeared with tar; another to be moistened with lime and pot-ash dissolved in water; a third with soap-suds and lime added to them; and many both nectarine and peach-trees with soap-suds alone. This was done by means of a brush before any flowers appeared, and was repeated thrice on different days; but to my great disappointment, when the leaves appeared, they became affected with the aphid as on former years. I also afterwards dipped many nut-leaves crowded with the aphid in strong infusion of tobacco, for a few minutes, as the leaves hung on the trees without, as I believed, destroying the insects; though some of them appeared for a time to be rendered torpid.

Nevertheless on covering a low nut-tree with some sheets of brown paper sewed together, and throwing the smoke of tobacco under it from a proper pair of bellows, great numbers of aphides were killed, many of which dropped from the upper leaves on those below them, and many adhered motionless to the under surfaces of the leaves. The fine powder of tobacco called Scotch snuff sprinkled on the aphides by turning up some of the leaves quickly destroyed them.

As walnut-leaves may be had in great quantity in the autumn, and the whole plant of *senecio jacobæa*, rag-wort, at any time, both which are probably deleterious to insects, as they seem never to be injured by them, these might be procured at small expence, and might probably, when dried and burnt, produce a smoke equally destructive to them.

Fifthly. The most ingenious manner of destroying the aphid would be effected by the propagation of its greatest enemy, the larva of the aphidivorous fly; of which I have given a print, and which is said by Reaumeur, Tom. III. Mem. 9. to deposit its eggs, where the aphid abounds; and that, as soon as the larvæ are produced, they devour hundreds around them with the necessity of no other movements but by turning to the right or left, arresting the aphid and sucking its juices. If these eggs could be collected and carefully preserved during the winter, and properly disposed on nectarine and peach-trees in the early spring, or protected from injury in hot-houses; it is probable, that this plague of the aphid might be counteracted by the natural means of devouring one insect by another; as the serpent of Moses devoured those of the magicians.

Mr. Horrocks of Derby shewed me this larva of the aphidivorous fly, which I saw devour two or three aphides, and Mr. Swanwick of this town at my request made an accurate drawing both of the larva and fly, which he kindly favoured me with, accompanied with the following note.

“ On August the 4th Mr. Horrocks obligingly sent me an aphidivorous larva in a box on a leaf of a plum-tree, on which were a number of aphides; and I had almost immediately the pleasure of seeing it eat one.

“ The method of taking his prey is thus: he is like the sloth in his disposition, for he does not ramble about, while he has food around him. He only lifts up his head, and strikes it down again, extending it in various directions, as if he was blind, and repeating the above ac-

tion. If by so doing he happens to feel an aphid, he immediately seizes it by the back, lifts it up and poises it in the air, as if to prevent it from liberating itself by its struggles against the surface of the leaf, or that it may fall more easily into the cavity of his mouth. In this position he holds it, while he pierces it, and sucks the juice out of the body; which having done, he drops the skin, licks his lips round with his little black tongue, contracts his head, and drops it down; thus resting in perfect repose for some time, after which he repeats the same actions. But if he is in the midst of plenty, he seldom gives himself this trouble, but waits till an aphid touches him, when he immediately turns his head round, and with fatal certainty seizes him, poising him as before.

“For the purpose of seeing what fly was produced from this caterpillar, I procured him food for about ten days. During this time he eat a great number of aphides, and grew to about an inch in length; when he left off eating, contracted himself to about half his former length, fixed himself to the box by a little gluten, which he discharged from his mouth, and without casting a skin changed to a chrysalis.

“In this state he lay about ten or eleven days, at the end of which time he burst his cell, and came out a beautiful fly, of which the figure is a good representation.”

No. 1. The caterpillar with an aphid in his mouth.

No. 2. The chrysalis open at one end.

No. 3. The fly.

Another enemy to the aphid is said to be a beautiful small spotted beetle, called a lady-bird by the people. Several of these were seen on the nut-leaves, and are believed first to appear there in their larva state, and to feed on the aphid; they then change to a chrysalis, and lastly to a small wing-sheathed beetle; and finally, I suppose, they bore holes into the earth, as would appear from their possessing sheaths to their wings, and that they there deposit their eggs to be hatched.

hatched, and to climb the trees infested with the aphid in the ensuing spring.

Thus from the exertions of a few aphidivorous larvæ or caterpillars, from the poisonous juices of some plants, and from the bristly armour on the young twigs and leaves of others, the vegetable world is so far protected from the destruction, with which it has been, and is threatened, by the fine proboscis of this multitudinous insect, which in its manner of attack resembles that of the large bat of Asia, *vespertilio-vampyrus*; which is asserted by Linneus to drink the blood by night of servants, who sleep in the open air, *Syst. Natur.* p. 46; and is said by others to be so skilful an operator as not to wake the patient by the puncture, which it inflicts, as it agreeably fans them with its wings.

3. Many of the orchards of apple-trees in this country are liable to lose all their leaves by the depredations of caterpillars; the same occurs to gooseberry-trees in some gardens, and to cabbages in the latter part of the summer.

A few years ago I observed, that the blossoms of the quince-tree, before they were quite expended, were perforated by a fly; as the wound could be easily discerned like that on young nuts, when wounded by the curculio; and all the blossoms of a large tree were thus destroyed by a small caterpillar. And in this late summer of 1799 the apple-blossoms in this country are much injured by a caterpillar, which eats the seed in the pericarp of each blossom either before or at the time of its impregnation, the petals of the flower closing again over it and dying.

The leaves of many trees are renewed after having been totally destroyed in the early part of the season; as those of the apple-tree above mentioned, which had lost its leaves entirely by lightning; as the mulberry-trees in Italy, which are thus robbed of their first leaves to feed silk-worms, as the tea-tree in China, which is thus robbed for a fashionable potation. And lastly, as the euonymus, or spindle-tree, which

which in this country has its first crop of leaves almost perpetually destroyed by caterpillars. But though the leaves are restored after the depredation of this insect, yet there follows an irremediable injury to the fruit. See Sect. IX. 2. 6.

As the eggs of butterflies are in the autumn wisely deposited in situations, where the young can find proper food, when they are hatched by the warmth of the spring; those on apple-trees, and on gooseberry-trees, are frequently deposited on the leaves, as well as on other parts of the tree; and as these leaves fall on the ground, the eggs are thus covered and protected from the frosts, and the young caterpillars are believed to climb the trees in search of their food. If this be true, it would be an advantageous practice to rake together the leaves in orchards, and to burn them; which some have done from an idea, that the smoke thus produced was noxious to the eggs of insects deposited on the branches.

Some gardeners for this purpose rear their gooseberry trees on one stem only; and believe, that by tying a fringe round this stem the insects, which are hatched in the soil, if such there be, can not climb up the tree thus surrounded with a fringe; and as those caterpillars, which are already on the tree, let themselves down by a thread, when the tree is shaken, from the fear of being hurt by the vibrating twigs; if this thread be then broken, by moving a stick round under the tree, these insects cannot reascend. A paper recently tarred on the outside might be wrapped round the stem of the tree instead of the fringe with perhaps more certain success; but the tar should not be smeared on the bark of the tree, lest it should injure or destroy it.

It may be observed in the choice of apple-trees, that those kinds, which flower early, are less liable to the depredation of insects; and those, which flower late, are less liable to the injuries of frost. In apple-trees perhaps the former is in some situation the greater evil, but in pears I should suspect the latter, the blossoms of which are so often totally destroyed by one night's frost.

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The white butterflies, which deposit their eggs on cabbage plants, are seen flying about awkwardly in summer, and should be caught, and destroyed by the gardener. Or they perhaps might be invited and poisoned by a mixture of honey, and water, and arsenic; as a wealthy man in Italy was said to have poisoned his neighbour's bees. See Sect. VI. 6. 3. These cabbage-caterpillars would increase in destructive numbers, but are half of them annually destroyed by a small ichneumon fly; which deposits its own eggs in their backs, which are there hatched by the warmth of the animal, and live on the silk there secreted for its future nest; and eroding their way out spin small cocoons of their own; ten or twelve of which hang on each caterpillar; which thus perishes instead of changing into a butterfly. This I saw happen to a great many of them, which were put into a box on bran with a few cabbage leaves, and covered with gauze, a few days before they were ready to change into chrysolists. This ichneumon fly should therefore be encouraged, if his winter habitation could be discovered.

4. The variety of insects, which infest hot-houses, as the acarus, thrips, aphid, and cocci, and the means commonly used to destroy them by the smoke of tobacco, or by the powder of sulphur and tobacco, or by solutions of lime and sulphur, are described in Speechly's books on the Vine and Pine; but require some caution in their application. A friend of mine, by subjecting a wall-tree to the smoke of sulphur by hanging a matt before it during the fumigation, killed both the insects and the tree.

5. Other kinds of insects are produced beneath the soil, or occasionally retire into terrestrial habitations. Of these are the various families of snails, with and without shells, and other insects with sheaths over their wings, with which they are furnished to prevent any injury from the friction of the sides of the holes they make or descend into.

It has been lately supposed, that the great destruction of the crops
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of turnips, which occasionally occurs, is owing to the depredation of a white slug, or snail, which comes out of the soil before sun-rise in dewy mornings; and that by rolling the young turnips with a heavy roller before sun-rise for a few mornings, these pernicious insects may be destroyed, and add manure to the rising plants they have injured.

The white slugs in gardens are very destructive to many flower-stems, as they rise out of the ground, as to *dictamnus fraxinella*, *apocynum androsatifolium*, to *phaseolus*, kidney-bean, to *cinara*, artichoke, and many other plants. I well remember in one season favourable to their production in a garden by the side of the Derwent observing, that many artichoke stems above a foot high were eaten by them near the moist earth till they fell down, like trees felled by the ax. It has lately been asserted, that watering the ground with tar-water will destroy them; which may be made by adding a few pounds of tar to a hoghead of water, and well stirring it, without perceptible injury to the tar. A circle of lime round the flower-stems, or of salt, or even of bran in dry weather, are means of preventing the approach of slugs; and some gardeners lay a board lightly on the ground between the alleys, under which the slugs hide themselves when the sun rises, and are hence easily caught and destroyed.

The leaves of the young turnip are also believed to be destroyed by a fly; which, if it be of the *scarabæus*, or beetle kind, which arises out of the earth, may likewise be destroyed by rolling. The Chinese are said by sir G. Staunton to steep all their seeds in liquid manure until they swell, and their germination begins to appear; which they believe not only hastens the growth of the plants, but also defends them against insects beneath the soil; and that to this sir George observes it may be owing, that the Chinese turnips escape the fly so injurious to them in this country. *Embassy to China*, 8vo edit. Vol. III. p. 310. An observation of Mr. Guillet in the *Bath Agriculture*, Vol. II. Art. 44, seems to confirm this idea. He asserts, that when turnip seed is sown during rain, or has rain immediately after-

wards, that the first leaves are so vigorous that the fly never attacks them; or that the rain itself is so inconvenient to the fly, as to prevent its appearance. It is also asserted by Mr. Exeter in the Transactions of the London Society for Arts, Vol. XVI. p. 191, that the sowing turnips in drills deeper than by broad cast, accelerates the growth of the plant by giving it more moisture; whence it sooner puts forth its rough leaves, and escapes the depredations of the fly. He speaks highly of the use of the drill, advises the rows to be one foot distant, uses three quarters of a pound of seed to an acre, and sows them from one inch and a half to two inches deep.

6. The great numbers and varieties of animated beings, which live under the soil, and sleep in winter, descending beneath the reach of frost, is truly astonishing. I once observed such immense numbers of small wing-sheathed insects, which I believed to be the *scarabæus foliitialis*, or fern-chaffer, as they were not one sixth part of the size of a May-chaffer, *scarabæus melolontha*, though much of the same form and colour; which arose out of the ground near the cold bath at Lichfield, that I guessed, that one or two emerged from every square inch of many acres of land.

The grubs or maggots, from which these wing-sheathed flies arose, I suspect in some seasons and situations favourable to their production to be very destructive to the wheat in spring, or the early part of summer, devouring the stem near the surface of the ground at the joint, which is sweet, till it falls down or withers, by which many crops were nearly destroyed this year, 1797, and that, I was informed, on some lands, which had been previously well limed.

Mr. Tull in his husbandry, speaking of wheat, advises not to sow it deeper than an inch, since the thread or caudex, which connects the lower or seminal root with the upper or coronal root, he believes to be then not so readily found by worms in the winter, as one three inches long might be, both on account of the greater length of the latter,

latter, and because insects do not rise so near the surface in the winter months.

Where this pestilential grub occurs, perhaps rolling the land early in the mornings in the spring might crush them. And when the fly is seen to come out in such abundance in the summer evenings on grass land or fallows, it is probable, that rolling the ground in the evening might prevent the return into the earth both of these and of the May-chaffers to deposit their eggs, and thus prevent their future progeny; or during their grub state, when they exist at the roots of wheat above or just beneath the surface of the soil, perhaps flaked lime might be sprinkled over the crop in powder, or sea-salt in powder, which might be washed down the stems of the corn in a wet day, and destroy the insect without injuring the vegetable; or lastly, by tar-water; all which might be first tried on a small part of a field; for as lime is not all of equal purity, it is not all of the same strength or causticity.

Another insect is said to injure wheat when in flower, and is supposed to be the thrips *physapus* of Linneus, as mentioned in the transactions of the Linnean Society, Vol. III. But as it only attacks the late flowering stems, it may possibly be prevented by sowing the wheat early, if it should ever become a serious evil.

Some time ago an insect called a corn-butterfly committed great ravages in France while in its vermicular state, so as to ruin two hundred parishes. A cure for it was at length discovered, which consisted in drying the wheat in an oven before sowing it, and thus exposing it to such a degree of heat as would destroy the eggs of the insect without injuring the seed; or perhaps which hatched them without sufficient moisture to soften the grain for their support. See *Encycl. Britan. Agricult.*

Between Chesterfield and Plaistrey in Derbyshire I well remember above forty years ago to have seen for two or three miles together every leaf of the hedges devoured by the May-chaffers, *scarabæus*

melolontha, which hung on each other, where the foliage was destroyed, like bees in a swarm. And to have found in the same year, as it lay dead in a field near Chesterfield, a true locust, like a very large grass-hopper with very long and broad wings; which I preserved in spirits, and was informed, that many of them were found in other parts of England about the same time.

All these noxious animals might be destroyed or diminished by encouraging the breed of small hedge-birds, and perhaps of larks, and of rooks, by not taking their nests. I have observed, that house sparrows destroy the May-chaffer, eating out the central part of it; and am told that turkeys and rooks do the same; which I thence conclude might be as grateful food, if properly cooked, as the locusts or termites of the east. And probably the large grub, or larva of it, which the rooks pick up in following the plow, is as delicious as the grub called groogroo, and a large caterpillar, which feeds on the palm; both of which are roasted and eaten in the West Indies. The various species of linnets carry small caterpillars to their gaping young; and hedgehogs are said to devour snails, and on that account to be profitably kept in gardens.

When a severe frost occurs, before the ground is covered with snow, those insects, which do not penetrate deeply into the earth during their hybernation, as the shell-less snails or slugs, are liable to be destroyed, and probably many of the larvæ of the fern-chaffer and May-chaffer, as is seen by their diminished numbers in the ensuing season.

In China the aurelia of the silk-worm, after the silk is wound off, and the white earth-grub, and the larva of the sphinx moth, furnish articles at the table, and are said to be delicious. Embassy to China. Nevertheless all the caterpillar tribes may not be equally innocuous; as in this climate the hairy caterpillars, if laid between the fingers, where the skin is tender, I have observed to produce an itching, and leave some of their pointed bristles in the skin. And M. Vaillant,

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in his travels in Africa from the Cape, asserts, that both a black and a white hairy caterpillar becomes so poisonous, when it feeds on a large euphorbia, that the natives put them in bags, bruise them, and after a few days poison their arrows with them. But that they are less poisonous if they feed on less acrid vegetables.

There must be great difficulty in destroying the larvæ, or grubs, or caterpillars, of many insects, which are injurious to the fruits and kernels, as well as to the foliage of plants, by any chemical mixtures; as in this state, I suppose, some of them are uncommonly hardy or tenacious of life. Mr. Gouch affirms, that he kept the *curculio nucum*, or worm found in nuts, in brandy for seventeen hours, which recovered; and I remember putting a worm, which came from a person, who called it an *ascaris*, though it was above an inch long, and nearly as thick as a thin crow-quill, into a saturated solution of sugar of lead in water; which lived many hours without apparent injury. See Nicholson's Journal, No. 21, for November 1798.

7. A great number of bees, as well as of moths, and butterflies, must be very injurious to flowers, and consequently to the production of fruits, as all of them plunder the nectaries of their honey, and thence deprive the anthers and stigmas of their adapted nourishment, as mentioned in Sect. VI. 6. 3. This would be more destructive to the seminal products of plants, but that many of them possess means of defending their reservoirs of honey, and yet of exposing it to the influence of the air, some of them by long winding canals, as in the bottom of the tubes of the honey-suckles, trefoils, and larkspurs, *lonicera*, *trifolium*, *delphinium*; others by covering it with a hood, as in monkshood, *aconitum*; others by a gluten, as in catchfly, *filene*, and in sun-dew, *drosera*; others by contracting some part of their leaves or flowers, and destroying the hostile insect, as in *dionœa muscipula*, and in *apocynum androsæmifolium*; and finally, many other flowers have probably acquired the habit of secreting more honey

ney than is necessary for their own consumption, as *calceola* *suaveolens*, alpine colts-foot, and *polygonum fagopyrum*, buck-wheat. From all these contrivances the flowers of plants probably receive less injury from the depredations of bees, moths, and butterflies, in this country, and from the humming bird in tropical climates, than they otherwise would be subject to.

But besides the loss of much of their honey an abundance of bees must likewise injure the seminal products of vegetables by plundering the stamina of flowers of their anther-dust for bee-bread, as Mr. Hunter believes; and also of the wax, which covers the anthers for their defence against rain. Nevertheless, as mankind convert to their own purposes the honey thus collected by bees, and the wax, with which they fabricate their combs; and as the seeds of plants and their fruits are nevertheless in sufficient abundance; the depredations of bees are not counteracted like those of other insects, but on the contrary encouraged.

The following observations, which I made this summer, may be of service to those who keep bees, and which I shall therefore here relate. The bees of one society frequently attack those of another society, plunder them of their honey, and destroy most of them, perhaps all of them, in battle; in this respect resembling the societies of mankind! This war for plunder occurs more frequently than is commonly suspected. Last year I had one hive of bees totally destroyed, and the year before another, which I did not take means to prevent, though I saw the contest, and the number destroyed in the latter; but not early enough in the commencement of hostilities.

Last week, June 16, I happened to see a great number of bees on the wing near the mouth of my only hive, and supposed that they were about to swarm. In an hour or two, on again attending to them I distinctly saw it was a violent battle; and at night observed about a hundred dead bees on the ground, and on the bench before the hive. I then directed a board about an inch thick to be laid on
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the bee-bench, and set the hive on this board with its mouth exactly on the edge of this board, the mouth of the hive was also contracted to about an inch in length, and a semicircular hollow was made in the board immediately under the mouth of the hive. By this means the affailing bees were obliged to alight on the bee-bench, and then to climb perpendicularly up the edge of the board, on which the hive was now placed; and thus appeared to act with great disadvantage; and a much less number of bees appeared to be slain in this day's battle; whence it would be advantageous always to place bee-hives in this manner.

Nevertheless, as the war did not cease, I directed early on the next morning to remove the bee-hive to a distant part of the garden, and to a more easterly aspect, and found to my great satisfaction, that the hosts of the enemy did not follow; and that in a few hours the unaffailed bees resumed their work, as appeared by their going into the hive with loaded thighs; and though a few of them were seen on the following two nights resting on their old habitation, these were carried early on the ensuing morning in their torpid state to their new situation, and the war ended without extermination of either society.

IV. DESTRUCTION BY VERMIN.

1. The destruction of grain, after it is sown, by the field-mice, which mine their way very quickly under newly ploughed lands near the surface, is said by Mr. Wagstaff, in the papers of the Bath Society, Vol. VI. to be effected in some seasons to a very great extent. He adds, that the tussocks of wheat, seen to arise in many fields, are owing to the granaries of these diminutive animals; which he has often found to contain nearly a hatful of corn, which grows into a tuft, if the owner becomes accidentally destroyed.

Mr. Wagstaff also asserts, that they feed much on the young plants,
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as they arise from the seed, and multiply at that time very fast. He detects their habitations by small mounds of earth being thrown up on or near the apertures of their dwellings, or of the passages, which lead to their nests or granaries; and by following the course of these passages he found and destroyed the parents and the progeny.

Mr. Wagstaff recommends the taking up and dividing the tufts of wheat, thus sown in the autumn by the field-mice, and transplanting them in the spring; and also to thin other parts of a young crop, as they appear too thickly sown, which he esteems an advantageous practice.

Acorns when sown, and garden beans, and peas, are liable to be dug up or devoured by these voracious little animals, which may be destroyed by traps baited with cheese; or best of all by the encouragement of the breed of owls, so active in the pursuit of nocturnal vermin, and thence so useful to the gardener and farmer, who still permit their servants and children to destroy both their eggs and callow young.

2. This country was infested with two kinds of rats, the house-rat and the water-rat; but it is believed, that within the last half century the water-rat has destroyed the house-rat. The water rats possess some kinds of ingenuity similar to the beaver in the construction of their houses near the brinks of rivers and pools; which have two apertures, one above ground amongst the grass, and the other beneath the surface of the water; and unless they can hide their upper opening amid weeds or grass, they forsake the situation. Thus if a rim, three or four feet in breadth, round a fish-pond be kept so low as to rise only two, or three, or four inches above the level of the water; and if this be kept clean from high grass, or weeds, the rats will desert the pond.

I have seen a young water-rat devour a large leaf of water-plantain, *alisma plantago*, and therefore suppose that they occasionally prey on the foliage, as well as on the seeds and fruits of vegetables, and on young animals, as ducklings and rabbits. As these animals, like the
dog,

dog, are of a lascivious nature, and as some materials have a strong scent, resembling perhaps that of their venereal orgasm, they are liable to be attracted by such smells, as dogs are, on the same account, I suppose, inclined to roll themselves on putrid carrion; and male cats to eat marum, valerian, and cat-mint. On this account it is usual for rat-catchers to avail themselves of this propensity, and to mix essential oil of rhodium, or musk, with the poisonous powders of strychnos nux vomica, or of delphinium stavifagria, or perhaps of arsenic.

The great injury to vegetation effected by these rats consists in their making innumerable burrows beneath the soil, and feeding on the roots of a great variety of vegetables. Some new planted apple-trees I remember to have seen taken out of the ground with nearly the whole of their smaller roots eaten, and the larger ones peeled by these reptiles. They will also destroy young ducks, young rabbits, and young chickens; and devour with great avidity every kind of food, with which poultry and swine are usually fed; and are hence in many ways injurious in situations near water.

The subsequent receipts for poisoning this mischievous vermin are printed in the papers of the Bath Agricultural Society, and said to have been attended with great success. First, to a quart of oatmeal add six drops of oil of rhodium, one grain of musk, and two or three of the nuts of nux vomica finely powdered; make it into pellets, and put them into the rat-holes. This was at first greedily eaten, and did great execution, but the wise animals after a time ceased to eat it. The second consisted of three parts of oatmeal, and one of stavifagria, stave's-acre, mixed well into a paste with honey. Pieces of this paste were laid in their holes, and again did great execution. A third method of destroying them there recommended is by laying a large box down on its front side with the lid supported open by a string over a pulley; and by trailing toasted cheese, and a red herring, from their holes to this box; and placing oatmeal and other food in this

box, which they are for a few nights permitted to eat unmolested; and finally to watch them by moonlight, the inside of the box being painted white; and, when many of them are seen, to let down the lid; by which contrivance sixty of them were taken at once.

3. Moles, as well as rats, have occasionally increased so greatly in numbers as to much injure the agricultor; they perforate the earth near its surface, and are said never to drink, but to feed on the roots of vegetable, as well as on subterraneous insects; and though they are believed never to drink, yet they have been seen occasionally to swim over lakes of water to the islands which they surround, of which an ocular proof is related in the transactions of the Linnean Society, Vol. III. 1797. Some have recommended to inject the smoke of burning sulphur, or of tobacco, into their subterraneous mansions; but as the earth frequently falls in behind them, as they pass, or is accumulated behind them by their hindermost feet, as they perforate the soil with their foremost feet or hands, this method of attack can seldom succeed, unless the nest of the animal be near the fumigated aperture. Others have advised to pour water into their holes, which is equally inefficacious in general, though it may have effect in particular situations. Some also have baited traps with worms, and others have advised to put poison into their holes; but they are not to be attracted together like rats from their not appearing above ground.

The following method was related to me by Francis Paget of Elston near Newark, a very popular and successful mole-catcher, whom I once attended in his occupation to witness his operations. The moles have cities under ground, which consist of houses, or nests, where they breed and nurse their young; communicating with these are wider and more frequented streets, made by the perpetual journeys of the male and female parents; as well as many other less frequented allies or bye roads, with many diverging branches, which they daily extend to collect food for themselves or their progeny.

This

This animal is more active in the vernal months, during the time of the courtship of the males; and many more burrows are at this time made in the earth for their meeting with each other. And though these animals are commonly esteemed to be blind, yet they appear to have some perception of light even in their subterraneous habitations; because they begin their work as soon as it is light, and consequently before the warmth of the sun can be supposed to affect them. Hence his method of destroying them consisted first in attending their situation early before sun-rise; and at that time he frequently could see the earth move over them, or the grass upon it; and by a small light spade he frequently cut off their retreat, by striking it into the ground behind them, and then dug them up. He added, that by laying the ear on a newly raised mole-hill, the sound of the scratching mole might sometimes be heard at a distance, and direct where to find it; as the solid earth conveys small vibrations better, or to a greater distance, than the light air. And that a terrier dog, after having been accustomed to the business, was frequently of service in detecting by his nose the place of the mole beneath the soil, and by endeavouring to scratch the earth over it.

The mole he said generally suckles four or five, and sometimes six, young ones; which are placed considerably deeper in the ground than their common runs; and as these nests are sunk much deeper into the ground than their streets or bye-roads, and the mole-hills consequently larger, the earth on the summit of those mole-hills is generally of a different colour, and is raised higher than that of the other ones. These nests are to be dug up, having first intercepted the canal between them and the mole-hills in their vicinity, to cut off the retreat of the inhabitants.

The next important circumstance is to discover, which are the frequented streets, and which the bye-roads, for the purpose of setting subterraneous traps. This is effected by making a mark on every new mole-hill by a light pressure of your foot; and on the next morning

by observing whether a mole has again passed that way, and obliterated the foot mark; and this is to be done two or three successive mornings. These foot-marks should not be deeply impressed, lest it should alarm the animal on his return, and he should form a new branch of road, rather than open the obstructed one.

The traps are then to be set in the frequented streets, so as nicely to fit the divided canal. They consist of a hollow semicylinder of wood with grooved rings at each end of it, in which are placed two nooses of horsehair, one at each end, fastened loosely by a peg in the center, and stretched above ground by a bent stick. When the mole has passed half way through one of the nooses, and removes the central peg in his progression, the bent stick rises by its elasticity, and strangulates the animal. He added, that where the soil was too moist or tenacious, that the moles in passing the old runs sometimes pushed a little of it before them, and thus loosened the central peg before they were in the noose; in which case he fixed the peg a little faster in the trap.

By these means Francis Paget cleared many of the neighbouring parishes of this kind of vermin in a few days, or a week or two, and laid them under an annual tax for the defence of their territories from these invaders. And added, that some other mole-catchers had carried moles into those farms, whose occupiers refused to pay them an annual stipend, a practice which he scorned to use. I have detailed this method to prevent this imposition, and to enable every farmer to be his own mole-catcher, or to teach the art to his servants.

PLATE IX.

PLATE IX.

Exhibits the aphid, puceron, or vine-fretter, and the insects which destroy it.

Fig. 1. represents the aphid of the rose-tree without wings very much magnified, copied from M. Bonnet, with its antennæ before, and its two horns behind, which are not half the length of the antennæ, are immoveable, and said by Bonnet to be hollow canals from which the sweet juice called honey-dew is evacuated; lastly, with the trunk under its head in the position in which it penetrates the leaves. In some the horns behind are wanting, and little knobs supply their place, which Reaumur thinks supply the same sweet juice. That some possessing wings, and others not, does not distinguish the sexes is agreed by all observers.

Fig. 2. represents a magnified aphid of a pear-tree, from which a young one is suspended for some time after it is otherwise born.

Fig. 3. represents the aphidivorous larva, with an aphid in its mouth, and the chrysalis of the same insect, before it is transformed into the fly at fig. 4. All these were drawn from nature, and exactly resemble similar representations in the work of Bonnet.

Fig. 5. represents an insect from Bonnet, which he terms an aphid lion, as it so greedily devours the aphides. This insect is transformed into the fly at fig. 6.

Fig. 7. represents a spotted hemispheric scarabeus, called by some a lady-bird, into which the insect at fig. 8. is transformed, which is also said to be a great aphid-eater. *Oeuvres de C. Bonnet, T. I.*





PHYTOLOGIA.

PART THE THIRD.

AGRICULTURE AND HORTICULTURE.

S E C T. XV.

THE PRODUCTION OF FRUITS.

Buds immediately from seeds never produce seeds. Neither in annuals nor trees. As in wheat, tulip, apple-tree. Buds from the broad caudex of a tulip, and the long caudex of trees, are of different maturity. Leaf-buds changed into flower-buds at Midsummer, or flower-buds into leaf-buds by art. I. To produce fruit-bearing trees. 1. Seedling-trees. Their puberty. Ingraft walnut and mulberry trees. If unpruned young trees or espalliers bear fruit sooner than other standards? Buds on bended branches earlier and larger. An apple sour on one side. How to produce fine seedling-trees or flowers. Leaves of seedling-trees. 2. Root-suckers from apples, vines, briars, figs, are like ingrafted scions. 3. Scions from branches planted in the earth. A quick-hedge thus raised. Chinese method. Vines how raised by Mr. Michel. 4. An ingrafted scion sometimes affects the stock. Acquires vigour from a vigorous stock. On trees of the same genus. On trees of different genus. Subject to hereditary diseases, not to old age, like the parent tree. Summits die first. Talicotius's ingrafted noses. Sour apple on one side. Apply rind to rind in grafting. Flower-bud not proper for inoculation. Sweeter apples have whiter blossoms. Colour of black cherry and purple grape known by their red leaves in autumn. Lines from Virgil's Georgics. II. To increase the number of fruit-buds. Leaf-buds are furnished with new caudexes down the trunk. Flower-buds not so. Retard the production of new caudexes. Viviparous and oviparous progeny. Production of new caudexes, or bark filaments, are compound in ingrafted trees, and suddenly generated. 1. Bend down the viviparous branches,
and

and they become oviparous, and receive more nutriment. Apple-trees trained in horizontal circles. Nectarines and peaches trained on the ground. 2. Twist a wire or tie a cord round viviparous branches. Apple-trees become dwarfs by frequent ingrafting on them. 3. Wound or break a viviparous branch, or cut off a cylinder of the bark. The vessels of the alburnum sometimes act as capillary tubes. Decorticated oaks. Tapped birch and maple. Decorticate alternate branches about Midsummer. Decorticated roots produce root-scions. Grafted roots. Layers. Take bark off and replace it. Cut three or four circular incisions, or a spiral line. To make dwarfs. 4. Transplant a tree, or cut the roots, or confine them. Pluck up and transplant beans, brocoli, strawberries. Also crowd the roots of strawberries. Put a brick floor under fruit-trees. Confine lily of valley in pots. Orchis. Cucumbers and melons. 5. Cut away central viviparous branches. Why spurs are oviparous. Why terminal buds are viviparous. Effect of it. Management of melons. Management of vines. Pinch off viviparous secondary buds, and they become oviparous next year at the same eye. A longer heat to ripen the wood explained. If this could be practised on other fruit-trees. 6. Lines from Botanic Garden. III. To perfect and enlarge the fruit. 1. Shorten the oviparous branches. Cut away root-suckers. 2. Pinch off useless viviparous buds. Pick out secondary buds. And of melons. 3. Thin wall-fruits, and grapes. Mucor grows without light. 4. Tie waxed thread round twigs of fig-trees and pear-trees when in flower, to prevent new leaf-buds. 5. Give additional moisture, manure, and warmth. Moisture enlarges fruit by relaxing their cuticle, and preventing absorption from them. Of suckling gooseberries. Watering rice when in flower. Manure adds nutriment. Much warmth with much moisture both enlarges fruit and adds to its flavour. Hot-houses heated by steam. Pines cultivated in water. 6. Protect flowers and fruits from frost. A low situation is not proper for a garden. Walls covered with projecting coping stones are useful in spring, not in summer. Moveable coping sheds. Fire-flues in garden-walls. A secret in the management of them. Shade flowers from the sun. 7. Fruits ripen sooner if wounded, or gathered before they are ripe, or baked in the hot-house, or in an oven. IV. 1. To preserve fruit. Keep it from heat and cold, and from moisture. How heat and cold destroy the life of fruit. Congelation separates salts, vinous spirit, and vinegar, from water. Condenses clay. Repels mucilage. Thaw frozen fruit slowly. Preserve fruits in ice-houses, or by steam. 2. Gather fruit during

its acid state. Evaporate part of its water. Keep it cool. 3. Impregnate fruit with sugar. Brandy poisons mucor or mould. 4. Fruits preserved in brine, in vinegar, in spirit of wine, ratifie. V. Verses on pruning trees and melons.

THE objects of the culture of the farm or garden may be divided into the production of fruits, seeds, roots, barks, woods, leaves, and flowers.

We have repeatedly endeavoured to shew, that the buds immediately arising from seeds are not themselves capable of producing seeds neither in herbaceous nor in arborescent vegetables; but that the first bud from every seed is succeeded by a second bud more perfect than itself; and that by a third, fourth, or many more; each generation being more perfect than the preceding one, till they acquire a puberty, if it may be so called, or a power of producing sexual organs, and a consequent feminal progeny.

In those plants, which are called annuals, because their seeds are sown, and produce other seeds, in the same year, and then perish, some successive buds grow on each other, before a flower can be produced; as is seen in the stems of wheat, and sowthistle, triticum, fouchus; which consist of joints, which appear to be successive buds growing on each other.

From the tulip seed a single bud arises the first year with a circular flat caudex existing beneath it, on which one principal new bulb is formed annually more perfect than its parent, as is seen by the larger leaf; and also some less bulbs are produced around the more perfect one in the bosom of each rudiment of a leaf, which composes or encloses the principal bulb, as described in Sect. VII. 1. 3. and Sect. IX. 3. 1. and 3. 6. These less perfect bulbs round the principal one, after the principal one has acquired its puberty, or power of producing sexual organs, are of greater or less degree of maturity, as appears by their size; and thence I suppose must require more or fewer years, before they flower.

Similar

Similar to this circumstance of the tulip-root, the buds of trees, which first arise from the seed, produce annually other buds more perfect than themselves, till they acquire the power of seminal generation ; and afterwards not only a flower-bud is formed, which is in some trees the central bud on the extremity of the twig, as in pear-trees, and on the spurs of apple-trees ; but also many leaf-buds of greater or less maturity are formed around the principal, or flower-bud ; which require more or fewer years, before they obtain the maturity necessary to produce a flower.

It was shewn in Sect. VII. 1. 7. that every part of the long caudex, extending from a bud on the summit of a tree to the root, can produce a bud, like every part of the broad caudex of a tulip-root ; but those produced in the bosom of the leaf I believe generally to be the most mature ; and those which arise from a lower part of the caudex to be less mature, and will in consequence require more successive buds to proceed from them, before they can form a flower. Thus when the whole branches of a fruit-tree are lopped from the trunk, the new buds are produced from the lower parts of the caudexes of the branch-buds, which have been lopped off, and are therefore an immature progeny, and require some years before they can flower.

It hence appears, that a number of buds or bulbs in all vegetables must succeed each other from the seed, before a flower and consequent fruit can be generated ; but that these successive generations are more numerous or fewer in some plants than in others ; that they in some plants may only succeed each other annually ; in others perhaps many of them in the same summer, as in the herbaceous plants, as wheat ; and in those trees, whose annual joints have their pith divided from each other, as in vines. And lastly, that the number of these successive generations, or the times of their production, whether only annually, or many of them in one summer, may be diminished

nished or accelerated by art; and that in attending to all these circumstances consists the successful management of fruit-trees.

The new buds on deciduous trees in this climate are produced about Midsummer, as observed in Sect. IX. 2. 9; and it is believed by the Linnean school, that many of them at this time may be so affected by art, as to become either leaf-buds or flower-buds. At this season therefore the production of buds on wall-trees, or espaliers, or on standards, should employ the attention of the horticultor; as those seedling-trees produce leaf-buds only, which are too young to produce flower-buds; and as the particular shoots or buds of other trees are not so mature as to produce flower-buds; and lastly, as some trees flourish too vigorously, as it is termed, to produce flower-buds. The things to be attended to are the age of the tree, from which the graft was taken, which now forms a branch; the maturity of the particular buds, which you wish to encourage; and the vigour of the whole tree, or its tendency to produce leaf-buds in preference to flower-buds.

I. TO PRODUCE FRUIT-BEARING TREES.

1. There are four methods of procuring fruit-trees for the purposes of horticulture, by seeds, by root-suckers, by planted scions, or by ingrafted scions.

1. *Of Seedling Trees.*

It was observed above in Section IX. 3. 1. and 3. 6. that in tulips and hyacinths, and even in potatoes and onions, the bulbs succeed each other for two or three years or longer, before they produce flowers; and that the same happens to the buds of seedling-trees, which are many years a succession of leaf-buds only, before the propagation of a single flower-bud; for the power, which produces the

lateral germination of buds, seems to require a less mature organization than that, which is employed in the sexual generation of seeds; whence a kind of puberty of the plant seems to be acquired for the production of the seminal or amatorial progeny, analogous to the transformation of caterpillars into butterflies; which appears to be effected solely for the purpose of propagation.

M. Speechly, in his treatise on the Culture of the Vine, p. 49, seems to say, that seedling vines must be three or four years old, before they produce fruit; whereas a planted scion, or an ingrafted one, from an aged tree, will produce fruit the first or second year; and according to the observations of Mr. Knight, seedling apple-trees will not bear fruit till they are twelve or fourteen years old; and other fruit-trees in similar manner require some years after their birth from the seed, before they arrive at sufficient maturity to bear flowers. See Sect. VII. 1. 3. Hence he advises the horticultor to procure scions for grafting from such trees as already bear fruit; but pays no regard to the stock, into which they are to be inserted; and adds, that he believes, if scions from a bearing walnut or mulberry tree were ingrafted on a seedling one, that it would produce fruit in two or three years; which otherwise would not occur in less than twenty. Treatise on Apple and Pear. Longman, London. And hence we see the advantage of ingrafting on seedling orange or lemon-trees in our green-houses the scions taken from those, which bear fruit; as otherwise they would continue so many years before the buds would acquire sufficient maturity to generate flowers.

Some have believed that young trees will bear fruit sooner, if they are not pruned, but permitted to grow quite wild in large bushes. It is possible, that this may occur either from the unskilful horticultor pruning off all the terminal twigs, whose buds were forwarder in respect to age, than the lateral ones much beneath them. Or because the great number of new leaf-buds, proceeding from an exuberant branching head, may so crowd the bark of the trunk with
their

their caudexes, that some of them may sooner find a difficulty in forming their embryo caudexes, and may in consequence become flower-buds. But I much doubt, that this can frequently occur from either cause, as I think, I have seen espaliers bear some years sooner than standards, which were ingrafted at the same time, and from the same trees. And I have been informed of other seedling apple-trees, which have born fruit in not much more than half the time above mentioned by Mr. Knight.

It is much to be wished, that proper experiments were made on seedling trees by planting them as espaliers, or against walls, and bending down their branches below the horizon, since the difficulty of their generating leaf-buds might be thus increased; as they could not so easily form their embryo caudexes on the compressed bark of the bended branch; and the sap-juice for the nourishment of fruit-buds would be thus rather increased than diminished, according to an experiment of Dr. Walker, who found the buds at the extremities of bended branches to swell sooner in the season, and to become larger, than those of an equal height on the more upright branches. *Edinburgh Transactions, Vol. I.*

Mr. Bradley has mentioned an apple, which was sweet and boiled soft on one side, and sour and boiled hard on the other; and ascribed it probably to the real cause with much ingenuity in the year 1721, long before the publication of the system of Linneus. He ascribes it to the male farina of some neighbouring harsh apple-tree affecting at the time of the impregnation the stigma of the flower of a sweet one; and thus a production of different seeds might be generated in the same pericarp, and a consequent different kind of nutriment prepared for each; and thus the different parts of the apple become sour or sweet, which is analogous to a bitch producing different kinds of puppies at the same birth, resembling the different dogs with which she had cohabited. The same circumstance is said to have occurred in oranges and in grapes of different kinds.

By this method of applying the farina of one good variety of fruit, as of apple or pear, to the stigma of another good variety, it is very probable, that some very excellent new varieties of fruit might be produced from the seeds, which might supply for a century the orchards of the curious, instead of our golden pippins, and nonpareils; which are said to be superannuated, and so liable to canker as not to be worth cultivation. It is probable also, that new varieties of tulips and hyacinths, and of melons and cucumbers, as well as of all other vegetables, might be thus produced.

The following observations are from Mr. Knight's treatise on Apple and Pear, p. 47. "Every seed, though taken from the same apple, furnishes a new and distinct variety; and some of these will grow with more luxuriance than others; and the fruits produced by the different plants will possess different degrees of merit; but an estimate may be made of their good and bad qualities at the conclusion of the first summer by the resemblance the leaves bear to the highly cultivated, or to the wild kinds; as has been remarked by the writers on this subject of the last century. The plants, whose buds in the annual wood are full and prominent, are usually more productive than those whose buds are small and shrunk into the bark; but their future produce will depend much on the power the blossoms possess of bearing cold; and this power varies in the different varieties, and can only be known from experience. Those, which produce their leaves and blossoms rather early in the spring, are generally to be preferred; for though they are more exposed to injury from frost, they less frequently suffer from the attacks of insects, the more common cause of failure.

"The leaves of young seedling plants annually change, become more thick and fleshy, and assume more the character of the cultivated kinds. These external changes indicate some internal ones in the constitution of the plant, which may possibly be similar in their nature to those, which take place in animals between their infancy

fancy

fancy and the time, when they become capable of propagating their species.

2. *Of Root-scions.*

Root-suckers from bearing bur-apples, or from bearing codlings, are believed to become fruitful as soon as grafts from those trees; because they are a viviparous offspring, as well as the scions or twigs from the branches; and are therefore not similar to the oviparous progeny, or the young trees produced from seeds. This must nevertheless in great measure depend upon the age of the sucker; as those root-buds, which rise into suckers, are not formed or generated in the bottom of a leaf, but from a part of one of the long caudexes of a branch-bud; and will therefore, I suppose, require a succession of buds for some years, before they will acquire sufficient maturity to produce a flower; as the central buds from the bottom of a leaf I suppose to be much forwarder than the lateral buds from the same caudex; as is seen in the central or flower-bulb of a tulip, and its immature lateral bulbs from the same caudex.

Root-suckers from those trees, which have been ingrafted on the roots of other trees, as the robinia on the acacia, may arise above the grafted part, which is beneath the soil; but those root-suckers, which arise from trees, which were grafted above ground, are similar to the stock, not to the fruit-bearing head; which might have been a wild pear or wild apple; and will in that case produce crab-pears, or crab-apples, with thorny stems.

When a branch of a vine, or briar, or of many other trees, is bent down, and a part of it inserted into the ground with its summit in the air, it will emit roots at the joints, and become a new tree. So the rough knobs on the bark of a bur-apple-tree, I am informed, will shoot out roots, if surrounded with moist earth; and the branch may be then cut off, and successfully planted. And from almost every joint of a fig-tree roots will protrude, if surrounded even with a woollen

woollen shred, which happens to be frequently moistened by the dews or rain ; and the branch may be successfully bent down and planted in a garden-pot. All these, like suckers from the roots of seedling-trees, or like grafted scions, will become fertile, as soon as the tree, from which they are the offspring ; whether it be a seedling-tree or not.

This circumstance does not occur exactly similar in the insertion of buds from one tree into the bark of another ; as those buds, which do not arise from the bosom of a leaf, but from lower parts of the caudexes of a branch-bud, as from the bark of a branch, whose summit has been cut off, are less mature, I believe, than the summit-buds, or those which arise from the bosom of a leaf ; and will therefore require some years before they can produce flowers ; as is seen in those apple or pear trees, whose summits have been entirely lopped off. This is a new observation, I believe, and worth the attention of those, who inoculate the buds of one fruit-tree into another.

Root-suckers may probably be liable to degenerate in respect to their vigorous growth by hereditary diseases, owing to the too great age of the original plant of that variety, like the ingrafted scions from the branches. Whence it may be necessary to procure root-suckers of raspberry-plants, and of gooseberries, and even of artichokes, and strawberries, from such as have been raised from seed not too long ago, when any of these begin to degenerate.

3. *Of Planted Scions.*

The scions taken from the branches of many trees, if planted in the earth, will emit roots, and flourish in the same manner, as when they are grafted on other trees. This succeeds with great certainty, if an inverted glass be put over them for a few days to prevent their perspiring more at first, than their absorbent vessels can supply. See Sect. I. 1. I have been informed, that a quickset, or hawthorn
hedge,

hedge, *cratægus*, was thus planted and became a good fence considerably sooner than from sowing the seed.

The Chinese are said by sir G. Staunton to be unacquainted with the art of ingrafting, and to produce dwarf fruit-trees, which are brought to table loaded with fruit at their festivals, by surrounding a branch of a bearing fruit-tree at its bifurcation with a bag of earth, which is kept moist for some months; till the branch puts out roots, probably from the lips of a wound in the bark, and is at length separated, and transplanted into a pot. *Embassy to China*, Vol. II. p. 54. 8vo. edition; and it is then rendered a dwarf by repeatedly cutting out the central buds, as in the management of melons, as mentioned in No. 2. 5. and 3. 2. of this Section.

Vines possess so vigorous a power of vegetation, that the present most approved method of propagating them in grape-houses consists in planting their scions. The late Rev. John Michel of Thornhill, in Yorkshire, the philosopher, who discovered to the world the art of making artificial magnets, which had been concealed by Mr. Knight; whose friendship I long possessed, and whose loss I have long lamented; amused himself and family at vacant hours in his hot-house. The observations of a man of such accurate and universal knowledge are always worth recording; and though his ideas on this subject have already appeared in Mr. Speechly's *Culture of the Vine*, I shall here transcribe a part of one of his letters to me dated in May 1785.

“ The way in which we raise our vines we account our own; for I don't know, that it was practised by any body before we set the example. It is now pretty generally adopted however by the gardeners and nurserymen in this part of the world. Instead of leaving three or four eyes on the cuttings, as used formerly to be done, which made them awkward straggling things, we never plant more than a single eye to each, cutting them with as long a part below the eye as they can admit, without encroaching too much upon the next eye below; that is to say, we leave perhaps about half an inch,

or

or a little more, as it may happen, above it. These cuttings we plant by half a dozen or a dozen together, at the distance of three, four, or five inches, in the bark-bed, where it is pretty warm, but not so hot as to endanger the burning of the roots, when they shall come out ; and where it is also pretty moist, or else we water them. We plant them sloping so as to make an angle of about thirty degrees perhaps, a little more or less, with the horizon, the eye being highest ; but taking care that it also shall be covered about an inch with the bark, which is a very necessary precaution ; for though it ought just to *smell* the fresh air, it must be kept moist, to prevent the bud and shoot, when it comes, from drying ; otherwise it will very frequently die away presently after it has shot a little, or at best it will grow unkindly, not having yet made roots sufficient to supply it with the sap necessary for its support ; which will not be the case, if the bud is sufficiently covered at first, and till it has acquired more roots.

We generally plant our vines in this way, about the beginning or middle of January ; and if the bark is pretty warm, and as moist as it should be, the cuttings will begin to push both at top and bottom in about a fortnight or three weeks at the most. When the vines have shot a little, perhaps three or four inches, but before the roots are got too long, (in which case it would be impossible to avoid breaking them by removing, on account of their extreme tenderness and brittleness) we displace a good deal of the bark very near them, till we can throw them down all together, which shakes the bark very gently from their roots ; so that one may disengage them sufficiently easy, and without much hurting them. We then plant three or four of the most promising and thriving ones out of the whole number singly in small pots in earth, which has previously stood in the hot-house a day or two to get warm, letting the roots drop down on a little earth at the bottom, at first, as they conveniently can, and then covering them with more earth carefully, till the pot is properly filled, and the stem about three or four inches long, as I said before,

before, standing in the middle; and then plentifully watering the earth to settle it to the roots. We now plunge them again in the bark, where in five or six weeks, more or less, they will have filled their pots pretty well with roots; when they will begin to shew by their little progress, and the smallness of the shoots, that they want more room. We then take them carefully out of these small pots, disturbing the ball of earth as little as possible, and put it all together into larger pots, putting a little fresh earth at bottom and round about, and watering well as before; and we then again plunge them into the bark.

“ By about the latter end of May, or beginning of June, the best of them will be four or five, or perhaps six feet high, and ought now to be removed, disturbing the roots as little as possible, into the natural ground, where they are to remain. If this is done carefully, and the earth well watered about them to settle it to their roots, they will frequently begin growing again almost immediately, but at least in three or four days; and will then often shoot in the hot-house two inches in a day, and by the end of the year will have shot from eighteen or nineteen, to three, four, or five and twenty feet. Though we approve of this as rather the best, yet if these cuttings are planted in the same way either singly in small pots, or two or three together in each, with earth, instead of planting them in the bark, destroying all but the best one, when they have shot a little, and plunging them either in the bark, or in default of a bark-bed, in a common hot-bed, they will do equally, or nearly equally well; only taking care, that the hot-bed is not too hot, so as to injure the roots, of which there is sometimes danger.”

4. *Of Ingrafted Scions.*

The art of ingrafting trees is of great antiquity, and is attended with numerous well known advantages, but is not yet arrived to its

utmost perfection ; for it is not yet certainly known, whether the ingrafted scion gives or takes any property to or from the tree, which receives it, except that it acquires nourishment from it.

There is one instance recorded by Bradley, where the scion of a variegated jassamine gave variegation to the leaves beneath it of the unvariegated jassamine, on which it was ingrafted, though the graft itself perished. See Sect.V. 1. This seems to shew, that a communication of juices exists between the graft and the stock ; and that thus some change in the colour of the leaves of the stock might be occasioned by the inosculation of the vessels of the new bud with those of other buds in its vicinity. Thus if a scion of a purple grape was ingrafted on a white one, the leaves of the latter might probably become somewhat red in the autumn, like those of the purple-vine ; but there are no instances recorded, where this communication of juices from the graft to the stock, or from the stock to the graft, has varied the flavour or the form of the flowers, or fruit of either of them.

For though the same vegetable blood passes along both the upper and lower part of the caudex of the new scion, which extends from its summit on the branch to its base in the earth ; yet the molecules secreted from this blood are selected or formed by the different glands of the part of the caudex, which was brought with the ingrafted scion, and of the part of it which remained on the stock, in the same manner as different kinds of secretions are produced from the same blood in animal bodies.

Some have nevertheless believed, that scions, ingrafted on more vigorous trees of the same genus, have acquired greater vigour in the growth both of their leaf-buds and fruit-buds. Mr. Speechly asserts, that he has improved many kinds of vines by ingrafting those, which bear small grapes, and which have generally weak wood, on stronger ones, which he has often experienced ; and recommends the Syrian vine to graft upon, and prefers those, which were raised from seed

for this purpose; and the contrary seems to appear, where more vigorous scions have been ingrafted on less vigorous stocks; as apple-scions on crab-stocks; where in a few years the part above the grafted joint becomes much larger in diameter than that below it.

Grafted scions succeed well in general on trees of the same genus, as in the common ingraftment of fruit-trees; so the laurel, *prunus lauro-cerasus*, will grow on the common cherry, *prunus cerasus*, and produce a tall evergreen tree. But there are said to be instances also of success in the ingraftment of trees not only of different genera, but even of different orders, and classes; as I have been informed, that apple-scions, *pyrus malus*, have grown, when ingrafted on hazels, *corylus*. And one of the fathers of the Carthusian order is said to have succeeded in grafting a vine, *vitis*, on a fig-tree, *figus*; and a jessamine on an orange. Travels in France and Italy, by E. Wright. It is hence probable, that many new discoveries might be made by more frequent experiments on this subject.

It nevertheless appears, that in grafted trees, though the stock annually becomes covered with a new bark, as well as the graft, yet it does not change its nature; since any new buds, which come out from the stock afterwards, are similar to the stock, not to the graft; and in many trees the graft grows so much faster as to become nearly of double the diameter of the stock, as is frequently seen in old cherry-trees, and is spoken of in Sect. VII. I. 7.

Thus the buds of fruit-trees, like the bulbs of tulips, when raised from seed, annually improve in their colour, length, thickness, and often in the shape of their leaves, for a certain number of years; and then acquire a male, or a female, organ of reproduction, as in the classes of monœcia, and diœcia; or both, as in hermaphrodite flowers. After this period the central buds and bulbs annually produced are in every respect similar to their parents, as mentioned in Sect. VII. I. 3. except in the nearer progress to old age of the tree, or of the bulb-progeny; and the consequent tendency to hereditary diseases. But the

lateral buds from the lower parts of the caudex of the central ones, which are not generated in the bosoms of leaves, are of a more immature kind, and in that respect do not resemble the central bud, or bulb; but require some years before they flower.

Mr. Knight has observed, that the grafts from those fruit-trees, which have been in public estimation for a century or two, are now so liable to canker, that they bear very little fruit, and are not worth cultivation; which he ascribes to the age of the tree; as a graft he says is simply an elongation of the parent tree. And as it demands some years to acquire the puberty necessary for sexual generation, so it may become weak and inirritable by age, and perish about the same time with the original tree; which is somewhat countenanced by another remark of Mr. Knight, that the summits, or long extremities of old trees, frequently die many years before some smaller branches from the trunk, which continue to flourish, as is frequently seen in old oaks as well as in fruit-trees; and which he might suppose to be occasioned by the greater age of the terminal buds than of the lateral ones, as well as from the greater length of their absorbent vessels, and the consequent greater resistance to the ascent of the sap-juice, which may also be sooner impeded, or totally stopped by the inirritability of old age.

Nevertheless as the buds of trees are successive progenies, and cannot therefore be liable to old age, as they die annually; the degeneracy of the buds of very old trees, or of those which have long succeeded each other by their lateral, and not by sexual generation, must arise from their being liable to hereditary diseases only, and not to hereditary improvements, as observed above in Sect. XIV. I. 6.

That the degeneracy of some plants is owing to hereditary diseases, and not to old age, appears from their continuing for long uncounted periods of time after the production of these diseases, as berberries without seeds, and vines without seeds, and strawberries without fruit, though probably with seeds, as the barren hautbois
strawberries,

strawberries, which bear no fruit, so called, have perfect stamina and pistilla, as I this day observed with a good lens; to which may be added those female figs, which have no aperture to admit impregnation, and the monstrous double flowers, which have lost the power of seminal propagation, and some mule-plants, which never possessed it.

We have nothing in the animal system, except in the polypus, and a few obscure insects, similar to lateral generation; and cannot therefore decidedly argue on this subject. Nor have we any thing similar to ingraftment in animals, except that of inflamed parts growing together, the transplantation of teeth, and construction of artificial noses from the skin of the patient's arm, seriously delivered by Talicotius, with many engraved plates in a work on that subject. But this ingraftment of noses was unfortunately burlesqued by the author of *Hudibras*; and perhaps this ingenious idea of Mr. Knight, that the ingrafted scion becomes diseased by age, and perishes about the same time with the parent tree, may be liable to a similar ridicule by some future writer on gardening.

So learned Talicotius from
The brawny part of Porter's bum
Cut supplemental noses, which
Would last as long as parent breech;
But when the date of Knock was out,
Off drop'd the sympathetic snout.

CANTO I. l. 281.

There is an apple said to exist at New York in America, which is asserted to be sour on one side of it, and sweet on the other side; and to have been produced by flitting a scion of a sour apple, and another similar one of a sweet apple, taking care to cut the buds of each scion with a very sharp knife exactly in half, and by applying them and binding them nicely together, and then ingrafting this double

scion

scion on a tree. I mention this, as it is related by Mr. Jay in the communications to the Board of Agriculture, Vol. I. part 3 and 4, p. 362; and is referred to in the Memoirs of the American Academy, Vol. I. p. 386. But there must undoubtedly have been some mistake in respect to the production of such an apple by any method of grafting, and which is so well explained as above by Mr. Bradley.

It only remains here to add in respect to grafting, that it is necessary to apply the bark, which contains or consists of the caudex of the young scion, exactly to the bark of the branch, into which it is inserted, or applied; and then all species of ingrafting succeeds, whether it is performed on a branch or on a root; and whether by excision, or inoculation, or inarching. But I suspect, that where a single bud is inoculated, it has often failed from the unskilful operator having selected a flower-bud instead of a leaf-bud; which probably unites its caudex to those of the stock with less vigour, and certainly dies after it has ripened its seed; or by his imprudently holding the bud in his mouth, as he ascends the ladder, or while he makes the incision, and thus destroying it by heat, as I once observed. A leaf-bud may in general be distinguished from a flower-bud by its being sharper pointed and less spherical.

Where the summits of very young scions of only a few weeks old are to be used to ingraft with and upon, it may be necessary also to apply the pith exactly to the pith; as this summit bud is yet a primary being, and not like a lateral one, whose whole caudex exists in the bark, which adheres to it, when it is taken off for inoculation.

The choice of buds for the purpose of inoculation is probably of more consequence than has hitherto been imagined. As we have endeavoured to shew, that buds from parts of the bark distant from the central bud, and which are not generated in the bosom of a leaf, are in different states of maturity; they must require more years before they can produce a sexual progeny of flowers, and a consequent
feminal

feminal offspring, with the reservoir of nutriment, or fruit, which attends it. A subject which is new, and merits to be further inquired into.

It is curious to observe, that when harsher fruits become sweeter, that the blossom becomes whiter, as is universally seen in those of our native crabs, and of our cultivated apples; and that the buds become larger, and the green leaves also become of larger area, and of paler complexion.

Thus Mr. Knight observes, “that the width and thickness of the leaves generally indicate the size of the future apple; and the colour of the black cherry and purple grape may be known by their autumnal tints; and that even in plants, which have sprung from seed in the preceding spring; as the tinging matter in the leaves of these plants is probably of the same kind as that, to which the fruits will in future owe their colour.” The leaves of the purple grape become quite red in autumn, as well as those of the geranium robertianum, and many other kinds of foliage, which I suppose may be owing to their abundance of acid, which uniting with the blue part of what constitutes along with the yellow part the green colour of vegetable leaves, converts it to red; as it changes the colour of blue flowers into red ones.

5. A translation of the beautiful lines in Virgil's *Georgics* on ingrafting may amuse the reader.

Where cruder juices swell the leafy vein,
Stint the young germ, the tender blossom stain;
On each lop'd shoot a foster scion bind,
Pith press'd to pith, and rind applied to rind.
So shall the trunk with loftier crest ascend,
And wide in air robusser arms extend,
Nurse the new buds, admire the leaves unknown,
And blushing bend with fruitage not its own.

II. TO INCREASE THE NUMBER OF FRUIT-BUDS.

The terms strength and weakness, in their usual acceptation, when applied to the vegetation of trees, are metaphorical expressions, or denote the effect or consequence, rather than the cause, of their bearing leaf-buds or flower-buds, as spoken of in Sect. IX. 2. 7. For the production of leaf-buds, or flower-buds, though it may be said to accompany the greater or less vigour of a tree, depends on the facility or difficulty, with which the long caudexes of the new buds, which constitute the filaments of the bark, can be generated.

Thus the new vegetable production formed in the axilla of a leaf about Midsummer, which is called a leaf-bud, consists of many embryo buds, perhaps twenty or thirty, which are to form the next year's shoot; and each of these must be furnished at the same time with a long caudex in miniature, extending from the leaf or summit to its radicle or base; which consists of umbilical vessels for its vernal nutriment, and of a continuation of other absorbent vessels, and of arteries and veins, as described in Sect. VII. 1. 7. which passes along the branches and trunk from the apex or leaf of the bud in the air to its base or radicle in the ground; and which thus forms the new bark, and contributes to thicken and strengthen the trunk and branches of the tree; because each new leaf-bud with its summit, caudex, and radicle, continues afterwards to adhere to the parent tree.

But the production in the axilla of a leaf, which is called a flower-bud, or fruit-bud, consists only of an individual vegetable with the rudiments of a number of flowers, with one caudex for its growth and nutriment; for as the seed falls from the tree, when ripe, no new apparatus of caudexes in miniature for each individual seed, as for each individual embryo-bud, is required to pass down the trunk into the ground to form a new bark; and thus to thicken and to strengthen the trunk and branches.

Add

Add to this, that not only the seeds require no new caudexes to pass down the trunk, but that probably the stamina and coral of each flower strike their roots only into the blood-vessels, which communicate with the bractes, like mosses or funguses, which grow on trees, or like cuscuta, dodder, viscum, mistletoe, and tillandsia, and epiden-drum; and therefore require no caudexes and radicles to pass down into the ground.

Whence it appears, that by rendering it more difficult for new buds to acquire new caudexes along the branches or trunk from the summit into the ground, the tree will be necessitated to produce flower-buds in preference to leaf-buds; a theory, which was first delivered in the Botanic Garden, Vol. I. canto 4. l. 470, note, and explains the whole art of the management of fruit-trees.

Vegetables therefore in respect to their mode of propagation are either viviparous or oviparous. The live progeny of vegetables consists of the buds, which rise on their branches in the bosom of each leaf, or on its long caudex extending down the bark of trees; or which arise on the bulbs, knobs, wires, or scions, from the broad caudex on the roots of herbaceous plants. The egg-progeny of vegetables consists in their seeds, with the previous apparatus of the flower, and concomitant nutriment in the fruit and cotyledons. And as plants, or parts of plants, are said to be in greater vigour, when the viviparous progeny is prevalent; as the caudexes of this adherent offspring form a new bark, and thence thicken and strengthen the trunk and branches; and to be in less vigour when the oviparous progeny is prevalent; as the seeds fall from the tree, and consequently require no caudexes to form a new bark, and thence to thicken and strengthen the tree. We shall generally use the word viviparous instead of vigorous, when applied to vegetables, which generate leaf-buds principally; and oviparous instead of weak, when applied to vegetables, which generate flower-buds principally; for the

words vigorous or weak may properly express the greater or less health of vegetables in both these situations.

The reader will please to observe, that in the Botanic Garden we have called the bark of trees an intertexture of the roots of each individual bud ; but that this is not accurate language, as the filaments, which constitute the bark, are each of them the caudex of a bud, or central part of it ; which has a leaf at its upper extremity, and a radicle at its lower one. And that each new caudex, or bark filament, is generated along the whole trunk of the tree by the caudex or bark filament beneath it ; as appears in those fruit-trees where one, or two, or three scions have been ingrafted on each other, as mentioned in Sect.VII. i. 7. for in these compound trees, when a bud arises from any part of the trunk, it is seen to resemble that part of the stock, and not to resemble the new grafted scion above it. We finally suppose, that this whole long caudex of a new bud is generally generated all at the same time by the sympathetic action of the parts of the parent caudex along with the bud in the bosom of the leaf of that parent caudex ; and that it is not gradually produced, as we first supposed, by the elongation of the roots of each budlet in the bosom of the leaves.

The following methods will contribute to prevent the young buds from so readily acquiring new caudexes on the trunk of the tree ; and will therefore retard the generation of leaf-buds, and consequently assist the generation of fruit-buds ; and should be executed about Midsummer, or soon after, as at that time the new buds are formed.

1. *The first method consists in bending the viviparous branches to the horizon, which converts them into oviparous ones*, for by the curvature of such branches the bark will be compressed on the under side, and extended on the upper side of the curve, and its vessels on both sides will be contracted in their diameters, and thus the difficulty of producing new caudexes for the generation of embryo leaf-buds will

be increased, in whatever state of miniature they may be conceived to exist.

A curious fact seems to be established by the experiments of Dr. Walker in the first volume of the *Edinburgh Transactions*, which shews, that the bending of a branch even below its insertion into the trunk does not impede the ascent or derivation of the vernal sap-juice into it; but on the contrary, that it rather appears to assist it, resembling in some measure a capillary syphon, as mentioned in Sect. III. 2. 4. which may be owing to the vernal sap-juice ascending principally, or entirely, in the sap-wood, as appears by the new leaves expanding to a certain degree on decorticated oak-trees, as shewn in Sect. IX. 2. 8. And as the vessels of this alburnum are more rigid, they may be less liable to contraction or coarctation by bending down the branch than the bark-vessels, as well as from their being placed within the latter, and therefore less liable to compression beneath the curvature, and to elongation above it.

Whence it appears, that the bending down a branch of a fruit-tree below the horizon does not diminish the nutriment of the fruit-buds, but rather increases it; as Dr. Walker observed these buds to grow sooner and larger at the extremities of the bended branches than on other parts of equal height.

It was asserted by Mr. Lawrence, that the more the branches of any tree are carried horizontally, the more apt that tree is to bear fruit; and that the more upright or perpendicular the branches are led, the more disposed is that tree to increase in wood; which he ascribes to the bending down of the branches impeding the circulation of the sap. *Art of Gardening*. Mr. Hitt in his *Treatise on Fruit Trees*, affirms, that if a vigorous branch of a wall-tree be bent down to the horizon or beneath it, it loses its vigour, and becomes a bearing branch; and therefore recommends his method of nailing the branches of wall-trees, and of tying those of espaliers, in an horizontal direction or still lower; as in this constrained situation there

must occur greater difficulty, I suppose, in the production of the new caudexes, necessary for the embryo progeny of buds, upwards or horizontally along the bended branch contrary to their natural habits, as well as from the compression of the bark beneath the curvature of the branch, and its extension above it; whence more flower-shoots are produced, which do not require new caudexes to pass along the bended branch; but which permit their progeny, the seeds, to fall upon the earth, and penetrate it with their new-roots.

In Lord Stafford's gardens at Trentham I remember to have seen many years ago some standard dwarf apple-trees with all their branches bent down, and fixed on a slight frame-work about a foot from the ground; which seemed to be uncommonly prolific, as a circle of white and purple flowers twenty feet in diameter on branches radiated from a center, appeared to a distant eye like a lunar halo, or a carpet of rich embroidery.

The greater production of fruit-buds on branches bended to the horizon must contribute, I should suppose, to the prolific effect of training nectarine and peach-trees on tiles laid on the ground, or on the gentle declivity of a bank of earth facing the south, which has lately been recommended by some one, whose name I do not recollect, who gained a patent for his discovery. And it is indeed probable, that both these modes of training fruit-trees, one of which may be called an horizontal wall-tree, and the other an horizontal espalier, would repay the labour of the horticultor; as they would be exposed to a more vertical sun in summer, which might more certainly ripen their fruit; and would be kept somewhat backwader in the early spring, by the greater obliquity of the sun-beams, and might be therefore less liable to injury from the vernal frost; and when in blossom might easily be covered in the night, when necessary, by mats thrown over them supported by stakes with horizontal poles on them.

2. Secondly. *The twisting a wire, or tying a waxed string, round the*

the viviparous branches of a tree, induces them to become oviparous, as observed by Mr. Whitmill, who bound not only the viviparous shoots of various wall-trees with strong wire, but also some of their large roots, and thus increased the product of his fruit. Bradley on Gardening, Vol. II. p. 155. And M. Buffon produced the same effect by a tight cord round the branches, which previously produced leaf-buds instead of flower-buds. Act. Paris. ann. 1738.

M. Buffon concludes from the above experiments, that an ingrafted branch bears fruit more copiously, and more certainly, from its vessels being compressed by the callus around the ingrafted junction, which may have this effect, and at the same time contribute by preventing the luxuriant growth of its leaf shoots to render the tree of more dwarfish stature. I am informed that many dwarf apple-trees, which are now planted in garden pots both in France and England, bear much fruit, and are elegantly placed in the centre of a desert at luxurious tables; and that the principal art of producing them consists in ingrafting them three or four times, scion on scion; so that the stem is compressed by the callus of three or four ingraftments before the branches are permitted to divaricate; and the trees are thus rendered beautiful dwarfs.

The effect of thus compressing the bark by a wire, or a cord, or by the callus round the junctures of the ingrafted scions, is undoubtedly accomplished by the increased difficulty opposed to the production of the caudexes for each new embryo leaf-bud, as above explained, and the consequent generation of flower-buds instead of them.

3. Thirdly. *The wounding, or breaking a viviparous branch, or cutting away a ring of the bark, as of pear-trees, or a semi-cylinder of the bark of other fruit-trees, induces them to become oviparous.*

Where young trees discover too great vigour, Mr. Lawrence advises to cut the most vigorous shoots two parts in three through, leaving a large notch, that the wound may not heal too soon; which he adds will both render them fruitful, make them more readily con-

form.

form to the wall or espalier, and preserve such as are dwarfs from too much aspiring in very strong branches, especially of pears; he recommends two or more such incisions to be made in the same branch.

Another method he proposes is to break the too vigorous branches half through with the hand, which he has practised with success in apricots and peaches, when the branches were formed directly forward from the wall, and these branches have continued several years to bear fruit, though some have occasionally died by effusing gum; and though these incisions and breaking the branches may be performed at any time of the year, he prefers the spring on account of the wet or frost of winter. Art of Gardening.

A complete cylinder of the bark about an inch in height was cut off from the branch of a pear-tree against a wall in Mr. Howard's garden at Lichfield about five years ago; the circumcised part is now not above half the diameter of the branch above and below it, yet this branch has been full of fruit every year since, when the other branches of the tree bore only sparingly. I lately observed, that the leaves of this wounded branch were smaller and paler, and the fruit less in size, and ripened sooner than on the other parts of the tree; and another branch has the bark taken off not quite all round with much the same effect.

The theory of this curious vegetable fact receives great light from the foregoing account of the individuality of buds. A flower-bud dies when it has perfected its seed, like an annual plant, and hence requires no place on the bark for new caudexes to pass downwards; but on the contrary leaf-buds, as they advance into shoots, form new buds in the axilla of every leaf; which new buds require new caudexes to pass down the bark, and thus thicken as well as elongate the branch. Now if a cylinder of the bark be destroyed, many of these new caudexes cannot be produced; and thence more of the buds will be converted into flower-buds.

In this curious circumstance the caudexes of the buds of the tree above the decorticated part seem to have emitted short radicles into the alburnum; the vessels of which must thus have acted as capillary tubes between the upper and lower caudexes of those buds; as capillary tubes will raise water by the attraction of their internal surfaces nearly to their summits, when they are not too high in proportion to their diameter; but water will in no case flow over their summits, but will always stand with a concave surface below the uppermost rim of the tube, in which situation it may readily be absorbed by vegetable radicles; and may be supplied from beneath by the sap-júice raised by the vegetable action of the absorbent vessels of the caudexes, whose radicles terminate in the earth.

It is customary to debark oak trees in the spring, which are intended to be felled in the ensuing autumn; because the bark comes off easier at this season; and the sap-wood, or alburnum, is believed to become harder, and more durable, if the tree remains till the end of summer. The trees thus stripped of their bark put forth shoots as usual with acorns on the sixth, seventh, and eighth joints, like vines; but in the branches I examined the joints of the debarked trees were much shorter than those of other oak-trees, the acorns were more numerous, and no new buds were produced above the joints which bore acorns. From hence it appears, that the branches of decorticated oak-trees produce fewer leaf-buds, and more flower-buds. And secondly, that the new buds of debarked oak trees continue to obtain moisture from the alburnum after the season of the ascent of the sap in other vegetables ceases; which in this unnatural state of the debarked tree may act as capillary tubes, like the alburnum of the small debarked cylinder of a pear-tree above mentioned; or as the vessels of the alburnum may not yet have lost their vegetable life, they may continue to absorb sap-júice or water from their radicles, and carry it to the buds at the summits by their spiral contractions as in the bleeding season.

It

It is probable, that if oaks were debarked in the summer, that much fewer leaf-buds would appear amidst the flower-buds; because many of the latter must be advanced too far, when the trees are debarked in the spring, to be converted into flower-buds by preventing the production of their caudexes, or by impeding the ascent of the nutritive sap-juice; which in these trees is lodged principally I suppose in the alburnum, as spoken of in Sect. IX. 2. 8. On the same account, when much sap-juice is taken in the vernal months from the birch or maple for the purposes of making wine in this country, or sugar in America, I am informed, that no great difference occurs in the respective numbers of flower-buds or leaf-buds, which then succeed; but that the general luxuriance of the tree is diminished; which evinces, that for the design of generating more flower-buds and fewer leaf-buds by partial decortication, it should be performed about Midsummer.

The cylindrical or semicylindrical decortication of a large root of a tree, as well as of a branch, is said to answer the purpose of increasing the production of fruit-buds by lessening the number of leaf-buds; but may be subject to two inconveniences; first, that the wounded root being near the surface of the ground may be liable to rot like the bottoms of hedge-stakes; or like timber, which is kept in moist cellars; or the posts of wooden bridges, which are alternately exposed to water and to air. A second inconvenience may occur from terrestrial insects having access to the alburnum of the root, which is often full of sweet sap-juice to invite them, and is otherwise generally defended by an acrid rind.

The parts of a tree immediately below a decorticated or a strangled branch or root will generally become viviparous, and will thence be said to be increased in vigour; that is, it will produce new leaf-buds, and those of a luxuriant appearance; because the injury of the bark of the branch or root will prevent the parts above from receiving so much of the nutritive sap-juice, as in their sound state;

state; and consequently the parts beneath will possess more of it; and also because these new buds are generated from a lower part of the caudex, and will thence be a few years before they will acquire that maturity, or puberty, which is necessary for the generation of flower-buds, or the production of a sexual or feminal progeny; whence by strangulating or decorticating the alternate branches of a pear-tree they will bear for six or eight years; and the other alternate ones will become in the same time strong and vigorous, ready to undergo a similar operation, when the former cease to be of further use; but the fruit will become smaller in size, though in greater number, and ripen earlier in the season.

In the same manner new root-scions are said to be produced by strangulating a branch of a root near the surface with a tight string, or by flitting a root near the trunk, Evelyn's Sylva; as in these cases the ascent of the sap-juice is impeded, and the part below becomes viviparous, or produces new leaf-buds for the reasons mentioned in the last paragraph; as is frequently seen where the end of a branch is lopped, or beneath the scar of the junction of an ingrafted scion. On the same account it is not uncommon to ingraft with success on roots taken out of the ground, and afterwards replanted; as the robinia on the root of acacia, and any other apples on the roots of the suckers of bur-apple, or codling, mentioned in Sect. IX. 3. 5.

For the same reason the roots of some plants, which are otherwise not easily propagated, will shoot up buds; if a part of them next the stem of the plant be half cut through, or raised out of the ground, and exposed to the air; as in pyramidal campanula, and geranium lobatum. And for the same reason the lateral branches of numerous shrubs, as well as of herbaceous plants, will put forth roots, when they are bent down into the ground, if they are previously wounded to prevent the free supply of the vegetable nutriment in its usual course, as in laying carnations, dianthus.

A method of converting the viviparous branches of pear and apple

trees into oviparous branches is described by Mr. Fitzgerald in the *Philosoph. Transact.* Vol. LII. and seems to be superior to the execution of a cylinder of the bark above mentioned; as the alburnum is not left naked after the operation. In the month of August he made a circular incision round the principal branches of several pear-trees, apple-trees, plum-trees, and cherry-trees, near the stems of each, quite through the bark. About three or four inches higher he then made another incision round the bark, and then a perpendicular one, joining these two circular ones, and separated the cylinder of bark nicely from the wood, covering it, and the bare part of the wood, from the air for about a quarter of an hour, when the wound began to bleed. He then replaced the bark with great exactness, and bound it round rather tightly with bafs, so as to cover the wound entirely, and half an inch above and below the circumcisions.

In about a month the bark began to swell above and below the bandages, he then unbound them, and found the parts quite healed. He rebound them slightly with bafs, and let them remain so till the beginning of the next summer, when he again took off the bandages, and found them all healthy; and every one of them bore plentifully that season, though it was in general reckoned a scarce fruit year.

He treated two young pear-trees in this manner, which never had yet had any bloom; on one of them he operated on the main arms, and on several of the less branches from those main arms; and on only one of the main arms of the other. The first, he says, bore a surprizing quantity of fruit in the next summer; and the circumcised-arm of the other bore a moderate quantity; though no other part of the tree had any appearance of bloom.

Mr. Fitzgerald afterwards took a cylinder of the bark from the branches of two young apple trees about the same size, as exactly as he could by measure; and changing them, bound them each on the other tree. The bark of one had a leaf-bud and two apples growing on it; the barks of both of them healed perfectly, the leaf-bud put forth

forth leaves, and the apples remained on and ripened; and both the branches bore so plentifully, that one broke with its load, and it was necessary to prop the other.

The theory of the success of these curious experiments confirms that delivered above concerning the scars made by the junction of ingrafted scions with the stocks; and it is probable, that three or four circular incisions through the bark on viviparous pear or apple trees, or a spiral incision, as described in Sect. IX. 2. 8. might answer the purpose without detracting and replacing the bark; as scars or callous circles would be thus produced, which might render it more difficult for the new caudexes of the embryo leaf-buds to be generated, or their parts united, and consequently increase the number of flower-buds.

Mr. Fitzgerald further observes, that he changed cylinders of the bark with equal success of nectarine and peach trees; and that the branches thus operated upon were retarded in their general growth; which coincides with the idea of repeatedly grafting one scion above another on the apple-trees designed for dwarfs to be set in garden pots, as described in No. 2. 2. of this Section.

4. *The transplanting a viviparous fruit-tree, or destroying some of its roots before Midsummer, or the confining its roots in a garden pot, or on a floor of bricks beneath the soil, will induce it to become oviparous.*

Mr. Knight, in his treatise on the Culture of the Apple and Pear, p. 83, has the following passage. “ In the garden culture of the apple, where the trees are retained as dwarfs or espaliers, the more vigorously growing kinds are often rendered unproductive by the excessive, though necessary, use of the pruning knife. I have always succeeded in making trees of this kind fruitful by digging them up, and replacing them with some fresh mould in the same situation. The too great luxuriance of growth is checked, and a disposition to bear is in consequence brought on.” The same observation was made by Mr. Lawrence, who took up trees which were too vigorous;

that is, which produced viviparous buds instead of oviparous ones, and replanted them to render them fruitful. *Art of Gardening. Lond. 1723.*

In transplanting trees for any purpose it may be observed, that they should not be replanted deep in the soil, since the most nutritive or salubrious parts of the earth are those within the reach of the sun's warmth, of the descending moisture, and of the oxygen of the atmosphere. And as the root-fibres of trees, like those of seeds, always grow towards the moistest part of the soil, as the young shoots and leaves grow towards the purest air and brightest light; it follows, that the root-fibres seldom rise higher in the ground than they were originally set, and seldom elongate themselves even perfectly horizontally; so that when a fruit-tree is planted too deep in the earth, it seldom grows with healthy vigour, either in respect to its leaf-buds or its flower-buds.

This curious effect cannot be produced by generally debilitating the tree from its want of due nourishment; because it is said to succeed best in very good soil, or by the addition of new garden mould, as before directed; but by rendering more difficult the production of radicles from the caudexes of the embryo leaf-buds; which descend to the finest ramifications of the old roots, and elongate themselves beyond the extremities of their ultimate fibrils; a great number of which roots being torn off by transplantation, or compressed in a garden pot, the production or progress of many of the new radicles must be impeded or prevented; and the numerous caudexes of new leaf-buds be in consequence formed with greater difficulty, whence an increased tendency to generate flower-buds.

For the same reason if beans, *vicia faba*, which are but a few inches high, be transplanted; they do not become so tall, but they flower and ripen their seeds sooner; because they can not so easily generate new leaf-buds. The same occurs in frequently transplanting brocoli, brassica; the plant does not grow so tall, but has earlier
flowers,

flowers, and in greater number; and it is hence better to pluck them up, than to dig them up, for the purpose of replanting them; as by that means more of the root-fibres are torn off, and the plants become almost totally oviparous.

It is well known, that the vessels of animal bodies are less liable to bleed, when they are torn asunder, than when they are cut with a sharp instrument; as their diameters are contracted, or their internal surfaces brought into contact with each other, in the act of extending them, till they break. Thus if the navel-strings of new born animals are cut instead of torn, they are liable to bleed to death; and there is a remarkable case of a miller's servant, who had his arm and shoulder bone, or scapula, torn off in a windmill without much loss of blood. This is mentioned to shew, that it may also be better to tear up roots, which are transplanted for this purpose, than to dig them up; as they may thence effuse less vegetable blood, and in consequence be less weakened by the operation.

In transplanting strawberries many of the roots being torn off, fewer leaf-buds, and consequent wires, are produced from the difficulty, which their embryo caudexes find in producing new radicles over the old ones to supply nutriment to the wires; till they bend down and protrude roots into the ground at their other extremities, whence a greater number of flower-buds are generated; on this account the roots of strawberries should generally be transplanted, or new ones from the wires should be cultivated, every third or fourth year, to prevent the too luxuriant growth of their wires; or a similar difficulty of producing wires or leaf-buds may be effected by crowding the roots of strawberries together, as some gardeners recommend; but I suppose by these means the fruit may become smaller from scarcity of nutriment, though more numerous.

A floor of bricks, or of stone, extended about two feet deep beneath the roots of wall trees, has been practised in some gardens from an idea, that the roots shot themselves too deep into some unwholesome
some

some stratum of earth ; and it has been observed, that the trees became better fruit-bearers. In some situations it is possible, this might be the cause of the new prolific property of the trees ; but I suspect it has occurred generally from the difficulty opposed to the number and elongation of the root-fibres, and consequently to the generation of the new caudexes of the embryo leaf-buds ; whence a greater production of flower-buds ensued.

In similar manner it is asserted by one of the Linnean school in the *Amœnitates Academicæ*; that some bulbous rooted plants, which seldom produce seeds in Sweden, will produce prolific seeds, if their roots be confined in a garden pot, till they crowd each other ; as those of the lily of the valley, *convallaria*. And that the orchis will bear prolific seeds, if the new root early in the season be severed from the old one, which has put up the flower-stem. This must occur in the former case from the difficulty, which the plants find to generate new offsets at their roots, which are their viviparous progeny ; and in the latter case from the new offset being destroyed ; whence in both situations more nutriment is expended on the flower.

On the same account it is probable, that confining the roots of cucumbers and melons in small garden pots would stop the too luxuriant growth of their leaf-buds, and render them sooner oviparous, if care was taken to supply them with water more frequently, and with sufficient nutriment by mixing with the water some of the carbonic black fluid, which has drained from a manure heap.

5. *If the central viviparous branches of a plant be cut away or shortened, the lateral ones will sooner or more completely become oviparous.*

1. There are many very small buds on the lower parts of large branches, which do not seem to grow to maturity, and in consequence produce neither new leaf-buds nor new flower-buds. There are other lateral shoots on many trees, which only push out a few inches, and are called spurs, and which bear fruit the succeeding summer at their extremities. In many other plants the lateral branches are oviparous,

except at the extremity, which is terminated with a viviparous bud; while the central branches continue long to generate only a viviparous progeny, as in vines and melons.

The first of these, or the unprolific existence of the buds at the bottom of large branches, may be owing in part to their feebleness of pullulation from the want of sufficient sunshine and ventilation; and also in part, like the spurs, and other lateral branches, to the difficulty they encounter in producing the embryo caudexes of new leaf-buds along the trunk; which is already occupied by those of the more vigorous vegetation of the central branches, which possess a greater share of sunshine and ventilation.

But the principal cause, which renders the spurs and lateral branches oviparous, results from the resistance the embryo caudexes of leaf-buds experience by the curvature of the lateral branch, where it joins the trunk, and the consequent coarctation of its vessels, added to the difficulty every lateral bud has to encounter from its own curvature at its exit from the parent twig; on which last account the central bud at the extremity of an oviparous branch is generally viviparous, because it has not any curvature at its exit. All this corresponds with the fact above described, that when the viviparous arms of wall-trees are bent down to the horizon, they become oviparous. See No. 2. 1. of this Section.

2. What then happens in all these situations when the central parts are cut away or shortened? First the dwarf buds at the bottom of these large viviparous branches, which are in part cut away, will find more room to push down the embryo caudexes of new leaf-buds; and will produce a viviparous progeny; and those at the bottom of oviparous branches, which are shortened by cutting off their viviparous extremities, will also now pullulate, and produce flower-buds for the succeeding year, owing to the derivation of some of that nourishment to them, which would otherwise have been expended on the summit-bud. Secondly, the spurs will generate an oviparous progeny,

geny, but will acquire more nutriment, because all the vessels of plants inosculate, as mentioned in Sect. IX. 2. 10. and will thence produce larger fruit, and more certainly ripen it. Thirdly, the other lateral branches will receive more nourishment, and become more vertical, and will thence find less opposition to the production of the caudexes, both of their flower-buds and leaf-buds; either of which may become stronger or more numerous according to the greater or less inclination of the branches to the horizon; and both of them may be more vigorous properly speaking; that is, they may become larger leaf-buds, or larger flower-buds, than others of the same tree.

3. Thus in the management of MELONS, which would grow into branches much too extensive for the artificial glass-frames of our climate, and would not have time to ripen their later fruit in our short summers; it is necessary first to check the vigour, properly so speaking, of the whole plant. This is done by washing the seed from the ripe fruit, which should naturally contribute to nourish it; and by keeping the seed four or five years, that the mucilaginous nutriment deposited in the cotyledons may also be in some degree impaired; it is also probable, that confining the roots of melons and cucumbers in garden-pots, if they were well supplied with nutriment, warmth, and water, might be advantageous for this purpose.

Secondly, as soon as the leaf appears an inch in diameter, experienced gardeners pick out the central bud, which causes an oviparous, though a more vigorous, lateral shoot; which therefore sooner bears fruit, and that of a larger kind; as it acquires more nourishment from the destruction of the central one.

And as these lateral branches are liable to produce other viviparous shoots at their extremities, after they have generated lateral flower-buds, it again becomes necessary to pinch off the viviparous extremities of them, not only to accommodate them to the size of the glass-frame, but also to supply them with more nutriment, which would otherwise have been expended on the viviparous summit.

The

The central bud, or summit, of the lateral branches, is generally viviparous, as well as of the central branches; because the embryon caudexes of its new offspring are opposed in the production along the bark by only one curvature at the insertion of the branch into the trunk; whereas the lateral buds of the lateral branches have the progress of the embryon caudexes of their new buds opposed by two curvatures, one of the bud to the branch, and another from the branch to the trunk.

There is another reason, why the lateral buds of many plants produce flowers sooner than the summit; which is, that the lateral buds of those plants, where the pith of the upright central shoot is not divided, are propagated from the central shoot, and are therefore one generation older; and have thus acquired the maturity necessary for amatorial reproduction. In other plants, where the pith of the stem is divided at every joint, the summit bud has been preceded by more generations, and is therefore more mature for the purpose of producing flowers, than the lateral ones, as in a stem of wheat; and probably in the artichoke, and on the spurs of some fruit trees, as of pears.

4. It was observed in Sect. IX. 3. 1. that in the stems of wheat three or four joints are formed above each other previous to that, which bears the ear; and that in many other annual or biennial plants two or three viviparous lateral shoots occur, as in artichoke, cinara; and falfafi, tragopogon, before the central one flowers. The same happens to the vine-shoots; two or three joints with a leaf and a viviparous bud at each are always first produced; and as each of these have a division of the pith between every joint, as remarked in Sect. I. 8. I suppose, that these joints are separate plants growing on each other like the joints of the stem of wheat; and that hence in vine-shoots three or four successive generations of leaf-shoots must exist, before the new shoot can attain sufficient maturity to form a flower; as the amatorial generation of seeds was shewn to require

higher animation, if it may be so called, than the lateral generation of leaf-buds. The same mode of growth occurs in the young shoots of oaks, and which is thus curiously accounted for.

The lateral branches of many mature trees, though they bear flower-buds on their sides, are generally terminated with a leaf-bud, as above explained; but it happens in some of them, and particularly to vines, that after two or three flower-buds are produced on a lateral branch, that it shall proceed to grow in length, and to produce leaf-buds at every joint above the flower-buds, as well as at the summit; which may be thus perhaps satisfactorily explained. After the third, and fourth, and fifth joints of a new lateral shoot have generated flowers, which require few or no more caudexes; room enough is left on the bark of the shoot for those above them to acquire the numerous new miniature caudexes of embryo leaf-buds, and where the new caudexes of embryo buds can easily be produced along the bark, and sufficient nutriment is supplied; all vegetables are more liable to propagate themselves by buds than by seeds.

Hence in the management of VINES, as well as of MELONS, it is useful at two or three joints above the last bunch of fruit to pinch off the viviparous end of the new branch, not so much to accommodate the length of it to the house, as to supply the growing fruit with more nourishment from the inosculation of the vessels of the caudexes of these viviparous buds, which are now cut off, with those of the oviparous ones, which remain.

A curious vegetable fact, which appears in the culture of VINES in hot-houses here presents itself to our notice. When a vigorous shoot advances without producing fruit-buds at the third or fourth joint, it is frequently permitted to grow in length to above twenty feet; but at every joint the new or secondary bud is pinched off, either soon after its appearance, or after it has shot out one or two joints. By this management of permitting the central summit of the shoot to grow till August or September, the eyes, whose buds have been

pinched off, do not put out a fresh during that summer; but new buds are formed at each eye, which germinate the next summer, and almost all of them produce fruit.

If however some of the shoots in the bosom of these leaves are pinched off too soon after their appearance, they are occasionally liable to generate new leaf-buds, which shoot out afresh from the same eye; and it is said, that these eyes, which have thus produced two leaf-buds in succession in one summer, will not generally produce buds of any kind in the succeeding summer; for as several of these joints in vigorous vines bear two or three buds from the same eye at the same time, so others bear them in succession.

The theory of these important facts may not be easy to investigate; it is commonly supposed, that pinching off the lateral shoots at every bud of a new vine-branch strengthens the next year's expected bud, by not expending so much nutritive juice; and that giving the vines a fortnight's artificial heat, after the summer heat lessens, ripens the wood for the production of the next year's fruit; but these are words, I imagine, without accurate ideas. I suppose, when each lateral shoot of this year's branch of a vine is pinched off, that its caudexes, which had already formed a part of the bark, coalesce; and may thus render it more difficult for the caudexes of the succeeding embryo bud in the same eye, which is to be expanded next spring, to be produced along the bark, by having previously occupied the situation which those new caudexes would require; and that thus the secondary buds of these eyes become flower-buds, which might otherwise have been leaf-buds.

The continued heat a week or two above the usual time of summer, which is said to ripen the wood, may contribute to dry and harden it, as well as to forward the growth of the buds; and thus both to render the protrusion of embryo roots more difficult, and consequently to produce flower-buds, and those of a larger kind.

Whether a similar method to this practised on vines could be ap-

plied with advantage in the management of other fruit-trees is a circumstance of great importance, and can only be determined by experiment. But as the first foliage of euonymus is generally destroyed by insects in this country, and yet a second growth of foliage is produced; and as I witnessed last year, that the whole first leaves of an apple-tree were destroyed, as was believed, by lightning, and which yet put forth an entire new set of leaves in a few weeks; is there not reason to conclude, that if the leaf-buds were picked out early in the season from a strong shoot of peach or apricot, either new leaf-buds might be produced in that summer, or flower-buds in the succeeding one, as happens to the vine-shoots above described; and that our wall-trees might be thus rendered more certainly prolific. And lastly, might not the clipping out with fine scissars the extremities of young vine-shoots, which would otherwise be barren ones, convert some of their tendrils into bunches by thus supplying them with additional nutriment, by preventing its expenditure in the elongation of the viviparous branch? This experiment might be the more readily tried, as some assert, that the barren buds may be distinguished from the prolific ones by their form before they expand.

6. *Arts of producing flower-buds.*

The following quotation, partly from the Botanic Garden, Vol. I. Canto 4. l. 465, may amuse the reader, and conclude the second part of this Section.

If prouder branches with exuberance rude
 Point their green germs, their barren shoots protrude;
 Lop with sharp steel the central growth, or bind
 A wiry ringlet round the swelling rind;
 Biseft with chisel sharp the root below,
 Or bend to earth the inhospitable bough.
 So, while opposed, no embryo leaf-bud shoots
 Down the reluctant bark its fibre-roots;

New germs shall swell with amatorial power,
 And sexual beauties deck the glowing flower;
 While the clos'd *petals* from nocturnal cold
 With silken veil the virgin *stigma* fold,
 Shake into viewless air the morning dews,
 And wave in light their iridescent hues;
 With graceful bend the *anther* by her side
 Shall watch the blushes of his waking bride,
 Give to her hand the honey'd cup, or sip
 Celestial nectar from her sweeter lip,
 Hang in wild raptures o'er the yielding fair,
 Love out his hour, and leave his life in air.

III. TO PERFECT AND ENLARGE THE FRUIT.

It is believed by some of the Linnean school, that flower-buds or leaf-buds may be converted into each other in the early state of their existence, as mentioned in Sect. IX. 2. 8. It is indeed probable, that either a flower-bud or leaf-bud may be generated instead of each other reciprocally, before either of them exists; but after either of them has obtained a certain degree of maturity, so as to be distinguished by its form being more pointed or more spherical; I suspect no addition or detraction of nutriment, or of the facility of the production of its embryo caudexes down the bark and radicles beneath can change its destination.

1. *Shorten the oviparous branches, when the leaves fall off, by pruning their viviparous summits, and cut away the root-suckers.* The summits of the lateral branches, as well as the erect ones, are furnished generally with viviparous buds; which in many wall-trees should be cut off, after the leaves fall in autumn; that more nutriment may be derived to the fruit-buds, which may occasionally become somewhat enlarged during the milder days of winter; as they are now certainly too far advanced to be changed into leaf-buds; and

if

if this pruning be deferred till late in the winter months, the flower-buds will not be quite so forward, as if it be performed earlier. For the same reason the root-suckers also should be cut away in the autumn, that all the nutriment, which they would otherwise expend, may be derived to the flower-buds, and induce them early to enlarge themselves.

2. *Pinch or rub off all useless viviparous buds in the spring or summer, as they occur.* In those trees where the fruit-buds arise on the new leaf-shoots along with the leaf-buds, and cannot therefore be sooner distinguished or approached, as in figs and vines, the summit leaf-buds should be pinched off two joints above the fruit-buds, as soon as they appear, that more nutriment may be conveyed to the fruit-buds. See No. 3. 4. of this Section.

And in the hardier wall-trees the new leaf-buds, which appear during the spring and summer months in wrong places, where they cannot be trained properly against the wall, or where they are too numerous, should be rubbed or pinched off, as they occur; whence more nourishment will be derived to the ripening fruit, and to those new leaf-buds which are to remain to produce future flower-buds.

And if the new buds, which are seen in their young state in the axilla of the leaves of the new shoots, were picked out by the point of a knife, or pinched off, where they grow long enough for that purpose, as the secondary shoots of vines in grape houses are pinched; it might probably induce those eyes to produce flowers in the succeeding year, as spoken of in No. 2. 5. of this Section, as well as contribute to enlarge the present fruit by the expenditure of less nutriment on the leaf-buds, an idea well deserving the test of experiment.

In the same manner in the cultivation of melons and cucumbers after the central bud is pinched off, as mentioned above, No. 2. 5. the viviparous extremities of the lateral branches should be also destroyed, as soon as a sufficient number of female flowers are impregnated; that

that a greater share of nutriment may be derived to them, instead of crowding the frame with new branches, whose fruit-buds would be too late to ripen in our short summers.

3. *Thin all those fruits, which are too numerous; pluck off apricots, peaches, gooseberries; and cut out many grapes from each bunch with scissars.* By the inoculation of the vessels of vegetables mentioned in Sect. I. 3, when any parts of a tree are destroyed, those in their vicinity become more vigorous. On this account when part of the fruit is taken away as early as may be, the remaining part acquires more nutriment. Add to this, that, where fruit is crowded, some of it becomes precluded from the sun and air, and in consequence does not perfectly ripen, and is liable to become mouldy; for mucor is a vegetable production, which like other fungi does not require either much light or air, as appears from the growth of some fungusses in dark cellars, and of common mushrooms beneath beds of straw, as mentioned in Sect. XIII. 1. 4.

4. *Prevent the production of new leaf-buds.*

In some pear trees the whole of the blossoms become sterile, and fall off without any apparent injury from cold, and this for many successive years. The same occurs sometimes to chestnut trees, *æsculus pavia*, after the flower the fructification entirely falls off; some of these might be male flowers, as Miller observes, but the whole could not be such. The same happens very frequently to the fig-trees of this climate, sometimes the whole crop falls off, when they are about the size of filberts; that is, while they are still in flower, which though concealed within the fig, must precede the swelling of the seeds, whether these be impregnated or not.

A correspondent fact occurred to me a few years ago. I had six young trees of the *Ischia* fig with fruit on them in pots in a stove. On removing them into larger boxes the figs fell off, which I ascribed to the increased vigour of the plants; as they protruded very vigorous shoots occasioned by the accumulation of new soil round their roots.

roots. Perhaps these plants might rather be said to have been in flower than in fruit, and perhaps these flowers were all male ones only, or accompanied only with imperfect female ones?

Whence I conclude, that about the season when the corals of these flowers with their stamens and stigmas die, the trees generate and nourish too many new leaf-buds, owing to the facility with which they can produce the new caudexes of these young buds down the bark; and that by the whole of the vegetable sap-juice being derived to the new buds for their present growth, or to form reservoirs for their future growth, the pericarp and seeds, whether impregnated or not, are deprived of their due nutriment and fall off. See Sect. XVI. 1. 4.

Hence I propose to tie waxed thread or fine wire round the twigs of pear-trees, which have usually miscarried, as soon as they are in flower, so as to compress, but not so as to strangulate them; or to wound the bark by a circular or semicircular incision, which might counteract their facility of procreating new leaf-buds; which I suspect would be more effectual in preventing the flowers from falling off, than pinching off the new leaf-buds, as they appear; which is recommended by Dr. Bradley in the management of fig-trees, and is done to vines in hot-houses; but which I found to be ineffectual on many fig-branches both in the natural ground and in pots, and ascribed its failure to the continuance of the efforts of the fig-tree to produce new leaf-buds; whereas in vines, I suppose, the grapes would ripen, whether the new leaf-buds remain or are destroyed. See No. 3. 2. of this Section.

Pontedera observed, that in the islands of the Archipelago some fig-trees bear in the spring many male flowers, and few female ones, the former of which fall off; and that they bear a second crop chiefly of female flowers in the autumn, which ripen in the ensuing spring. Anthologia. Can this occur in the fig-trees of this country?

Other figs are said not to ripen but to fall off before their maturity, unless

unless they be wounded by insects in their caprification, or punctured by a straw. A further investigation of this subject is much wanted to propagate figs with success in this climate. See Botanic Garden, Vol. II. note on caprificus. See also Milne's Botan. Diction. Article caprification.

5. *Give additional moisture, manure, and warmth, during the early part of the growth of fruit.* By additional moisture the fruit becomes larger; in hot-houses this may be effected two ways, one by watering the earth on which the vegetables grow, and another by producing steam by watering the warm flues or floors; which will afterwards in the colder hours be again condensed, and settle in the form of dew on the fruit and leaves.

By supplying vegetables as well as animals with an abundance of fluid, they are liable to increase in bulk, both because the external cuticle, which confines the growth of both of them, becomes relaxed, as is seen in the hands of those women, who have many hours been employed in washing; and also because the cutaneous absorbent vessels will thus imbibe more fluid from the external surface; and the cellular absorbents will therefore imbibe less from the internal cells, and consequently more mucus or fat will remain in them.

Thus in Lancashire, where premiums are given for large gooseberries, I am told, that some of those, who are solicitous for the prizes, not only thin the fruit of a gooseberry-tree, so as to leave but two or three gooseberries on a branch, but then by supporting a tea-saucer under each of these gooseberries, bathe it for some weeks in so much water as to cover about a fourth part of it; which they call suckling the gooseberry.

In some parts of the Carnatic, where rice is cultivated, they are said not to derive the water on it, till it is in flower; because that would induce the stem to shoot too luxuriantly, like our wheat-crops in wet-seasons; but, as soon as it is in flower, they find it expedient to flood it with water for the purpose of filling and enlarging the

ears, (Communications to Board of Agriculture, Vol. I. p. 355,) which it may effect both by relaxing the cuticle of the grain, and preventing the too great internal absorption of the mucus or starch deposited in the cells of it; and lastly by supplying it with more nutriment.

There are two circumstances to be attended to in giving water to plants; which are, not to water them during the hot part of the day in summer, nor in the evenings of spring, when a frost may be expected; in both these circumstances we may be said to copy nature, as rain is generally preceded by a cloudy sky, and is never accompanied by frost; though that sometimes follows it, and is then very injurious to vegetation.

When plants have been long stimulated by a hot sunshine into violent action, if this stimulus of heat be too greatly and too suddenly diminished by the affusion of cold water, or by its sudden evaporation, their vessels cease to act, and death ensues; exactly as has too frequently happened to those, who have bathed in a cold spring of water after having been heated by violent and continued exercise on a hot day. When severe frost follows the watering of plants, they are rendered torpid, and die by the too great and sudden diminution of the stimulus of heat; which is equally necessary to the activity of vegetable as to animal fibres; and in some instances the circulation of their fluids may be stopped by the congelation of them; and in others their vessels may be burst by the expansion attending the conversion of water into ice; or lastly, by the separation of their different fluids by congelation. See Sect. XV. 4. 1.

When an addition of manure can be procured, as where the black carbonic juice from a dunghill mixed with water, or soap-suds, which have been used in washing, can be employed instead of water alone; it must undoubtedly add to the nutriment, and consequently
enlarge

enlarge the size of the fruit by that means also, as well as by the additional water.

Where too much moisture is given without at the same time an addition of warmth, some inconveniences are liable to occur, as a less aromatic and saccharine flavour of the fruit. When therefore fruits become nearly ripe, less water should be given them, unless it is convenient at the same time to increase the heat, in which they are immersed, as may be done in some hot-houses; and then the flavour of the fruit may be heightened, as well as its size increased, as shewn by Mr. Bastard in the Philosophical Transact. who planted pine-apple plants in vessels of water, and placed these vessels near the top of the hot-house, or on the fire-flues, for the purpose of supplying them with a greater heat; and produced by these means both larger, as he asserts, and better flavoured pine apples.

On this important subject I shall transcribe his words, and shall only add, that steam from boiling water is now successfully used in some hot-houses for the growth both of vines and of pines, but must require some attention in the application of it; as it is occasionally conveyed through small apertures, which perforate a brick arch, which is constructed somewhat like the floor of a malt-kiln, where the water boils beneath the beds of bark or of soil; and is occasionally admitted into the room above, and thus supplies moisture and heat both to the ground and to the air of the hot-house.

“My hot-house is covered with the best crown glass, which I apprehend gives more heat than the common sort of green glass generally used for hot houses. In the front part of the house, and indeed any where in the lowest parts of it, the pine-apple plants will not thrive well in water. The way in which I treat them is as follows. I place a shelf near the highest part of the back wall, so that the pine-plants may stand without absolutely touching the glass, but as near it as can be. On this shelf I place pans full of water, about seven or eight inches deep; and in these pans I put the pine-apple plants,

plants, growing in the same pots of earth, as they are generally planted in to be plunged into the bark-bed in the common way ; that is, I put the pot of earth with the pine-plant in it in the pan full of water ; and as the water decreases, I constantly fill up the pan. I place either plants in fruit, or young plants as soon as they are well rooted, in these pans of water, and find they thrive equally well ; the fruit reared this way is always much larger, as well as better flavoured, than when ripened in the bark-bed. I have more than once put only the plants themselves without any earth, I mean after they had roots, into these pans of water, with only water sufficient to keep the roots always covered, and found them flourish beyond expectation. A neighbour of mine has placed a leaden cistern upon the top of the back flue, (in which, as it is in contact with the flue, the water is always warm, when there is fire in the house,) and finds his fruit excellent and large.

“ The way I account for this success is, that the warm air always ascending to the part, where this shelf is placed, as being the highest part of the house, keeps it much hotter than in any other part. The temperature at that place is, I believe, seldom less than what is indicated by the 73d degree of Fahrenheit’s thermometer ; and when the sun shines, it is often at above 100° ; the water the plants grow in seems to enable them to bear the greatest heat, if sufficient air be allowed ; and I often see the roots of the plants growing out of the holes in the bottom of the pot of earth, and shooting vigorously in the water.

“ It is not foreign to this purpose to mention, that, as a person was moving a large pine-plant from the hot-bed in my house last summer, which plant was just shewing fruit, by some accident he broke off the plant just above the earth in which it grew, and there was no root whatever left to it ; by way of experiment I took the plant, and fixed it upright in a pan of water (without any earth whatever) on
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the shelf; it there soon threw out roots, and bore a pine-apple that weighed upwards of two pounds." *Philos. Transact.* Vol. LXVII.

6. *Protect the early flowers and the late fruits from frost.* The vernal frosts are very pernicious to the early blossoms of apples and pears, and of all the tender wall-trees; various contrivances have been used to shelter them, as mats suspended before wall-trees; which in Denmark are said to be used to shelter them from the mid-day sun, as well as from the night-frosts; both to prevent them from flowering too early, and being thence exposed to severer frosts; and because vegetables suffer more from great cold, as well as animals, after having been exposed to great heat, as explained in Sect. XIV. 2. 2.

Those parts of vegetables, which are most succulent, suffer most from frost, as the young tops of tender trees, as of the ash, *fraxinus*, and weeping willow, *salix babylonica*; and also all other vegetables after having been exposed to much moisture, as to rain or dews; which probably may occur in part from the greater sensibility of the tender juicy summits of the present year's growth, and partly from the expansion of their frozen juices, which may burst the containing vessels.

An important question here occurs, is a low situation to be chosen for a garden? The greater warmth of low situations, and their being generally better sheltered from the cold north-east winds, and the boisterous south-west winds, are agreeable circumstances; as the N. E. winds in this climate are the freezing winds; and S. W. winds being more violent, are liable much to injure standard fruit-trees in summer by dashing their branches against each other, and thence bruising, or beating off the fruit; but in low situations the fogs in vernal evenings, by moistening the young shoots of trees, and their early flowers, render them much more liable to the injuries of the frosty nights, which succeed them, which they escape in higher situations. These fogs, which are seen by the sides of rivers, and on damp plains or valleys after sun-set, are converted into rime during the night. And as

at the time of these fogs there is generally no wind, the dew falls perpendicularly, and the rime is formed most frequently on the upper surface of objects, which may then therefore be more readily sheltered from it than at other times, when the freezing fog is blown forwards by the wind, and the rime is formed on one side of the branches of trees.

In some circumstances the rime is believed to defend the vegetables on which it is formed, by the heat it gives out at the instant of its freezing, and by covering them from the cold like snow upon the ground; and thence the black frosts, which are not attended with rime, are said to be more prejudicial. But where dew or mist descends on vegetable leaves before the act of freezing commences, and is in part absorbed by them; they become more succulent, and hence are destroyed by their fluids being converted into ice, and bursting the vessels already distended with more water, than they would otherwise possess. See Sect. XIII. 2. 2.

Mr. Bradley gives a decisive fact in regard to this subject. A friend of his had two gardens, one not many feet below the other, but so different, that the low garden often appeared flooded with the evening mists, when none appeared in the upper one; and in a letter to Mr. Bradley he complains that his lower garden is much injured by the vernal frost, and not his upper one. A similar fact is mentioned by Mr. Lawrence, who observes, that he has often seen the leaves and tender shoots of tall ash-trees in blasting mists to be frozen, and as it were singed, in all the lower parts and middle of the tree; while the upper part, which was above the mist, has been uninjured. Art of Gardening. In confirmation of this idea I well remember many years ago to have travelled sixty miles, partly in the valley of the Trent, and partly over adjacent hills, on the sixth of May; and to have observed that the new shoots of all the ash-trees in the valleys had their young extremities entirely turned black by the frost of the preceding night; but that on the hills they had escaped, which

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I at first ascribed to the trees being less forward on the hills, but believe it was more probably owing to the greater succulence of those in the valleys, and to their having been previously exposed to the moisture of the evening mist.

The precipitation or adhesion of moisture to vegetables, when misty air is blown against them, is well described by Mr. White in his history of Shelborne; who observed on a foggy day with some wind, that so much moisture was deposited on a tree, that it ran down upon the ground, and filled the ruts of a lane beneath it, which was dry elsewhere. On the same account in the early spring the grass is seen to become green sooner under the spreading branches of trees than in their vicinity. See Botanic Garden, Vol. I. note 26.

It is hence evident, that very low and damp situations are not to be preferred for gardens and orchards in this climate; and that it is in all gardens an object worthy attention to protect in the early spring the blossoms and the young shoots from being moistened by the descending night dews; for this purpose some have put coping stones at the top of the fruit-walls, so as to project six or eight inches over the trees. By the shelter of these coping stones the descending dews, which would moisten the young leaves and flowers, are prevented from falling on them, and in consequence no rime is seen in the morning on these trees. I had once an opportunity of observing some trees beneath a projecting coping to be much safer in respect both to their fruit and foliage, than those in their vicinity, and in the same aspect, where there were no coping stones over them.

But I am informed, that after the vernal frosts have ceased, this kind of shelter is certainly injurious to the growth and perfection of the fruit; which may arise from the same cause, namely, the want of the summer night-dews to moisten the fruit, and also the perpendicular sun-beams to ripen it. On these accounts I have proposed to make temporary sheds of boards to project eight inches from the walls, to be held on by iron hooks, which might easily be removed,

moved, as soon as the vernal frosts should cease; and in one experiment on a single apricot tree it appeared to succeed well.

From some experiments in a late volume in the Philosophical Transactions, it appears, that very much more rain was caught in glasses placed on the ground near a high church, than was caught in similar glasses on the roof of it; which evinces, that a much greater quantity of moisture exists in the lower parts of the atmosphere, and is precipitated from it, than from the higher parts; whence to protect the blossoms more effectually from the descending dews coping boards might be placed at every two feet or less above each other, with their front edges pointing upwards to the meridian sun in March, and ledges nailed on the back edges to convey the rain or dews towards the central part of the tree, where by another cross ledge at the end of each board it might be carried from the wall.

A similar inconvenience from autumnal frosts affects some of the late fruits, as figs and grapes, which might also receive advantage from replacing the coping boards in the autumn.

Another method of effectually guarding against the vernal frosts, and also the autumnal ones, is by building the garden-walls with fire-flues in them, which is now frequently practised. There is one secret necessary to be known, and well attended to, in the management of fire-flues; and that is in the first place to plant trees, which will open their flowers about the same time, against the same flue, and then diligently to observe not to put fire into this flue, till the trees, it is designed to assist, are in flower; since if the fire be applied sooner, the flowers are forwarded, and in consequence exposed to more danger from the severer frosts. One friend of mine, who diligently attends to this circumstance, assures me, that he never fails of producing a plentiful crop of excellent fruit.

And it is possible that one use of covering apricot trees, before they flower, from the mid-day sun, which is said to be practised in Denmark, may be to protract their time of flowering, and thus expose them

them to less danger from frost, as well as to prevent their irritability from being exhausted by the heat, and thus causing the night air to be more injurious to them.

7. *Fruits may be sooner ripened by wounding them, or by gathering them.* The wounds inflicted by insects on many fruits promotes their more speedy ripening, as well as those inflicted by capricification, mentioned in Sect. XIV. 3. 3. and in No. 3. 4. of this Section. It is said that cutting the stalk of a bunch of grapes half through, which has acquired its due size, will expedite the ripening of it; because it will then be supplied with a less quantity of new juices, and the change of its acerb juices into saccharine ones, which is partly a chemical, and partly a vegetable process, proceeds more rapidly. See Sect. X. 8. 1. On the same account the pears on a branch, which has had a circle of its bark cut away, will ripen its fruit sooner; and those annual plants, which are supplied with less water than usual, both flower sooner, and ripen their seed sooner.

To which may be added, that gathering pears from the tree before they are ripe, and laying them on heaps covered with blankets, is known considerably to forward their ripening, by something like a chemical fermentation added to the living action of the fruit, which advances the saccharine process with greater rapidity.

I have seen apricots at table, which I was informed were plucked from the tree, and kept some days in a hot-house, and thus became deliciously ripe; in the same manner as harsh pears ripen almost into a syrup during twelve or twenty hours baking in a slow oven; which occasioned the jest of a French traveller, who on being asked on his return, what good fruit they had in England, answered, that the only ripe fruit he happened to taste was the baked pear.

IV. THE ARTS OF PRESERVING FRUIT, as they depend on the prevention of the chemical processes, which produce their dissolution, ought to be here mentioned.

1. As life whether animal or vegetable prevents putrefaction, and as many fruits exist long, after they are gathered from the tree, before they become ripe and die spontaneously, and in consequence putrefy, as crabs, floes, medlars, and austere pears. The art of preserving these consists in storing them, where the heat is neither much above or below 48 degrees, which is the temperature of the interior parts of the earth; that is, in a dry cellar, or beneath the soil, or well covered with straw or mats in a dry chamber. As greater heat might make them ripen sooner, than they are wanted, by the increased activity of their vegetable life; and frost by destroying that life would subject them to putrefy, when they become thawed; as perpetually happens to apples and potatoes, which are not well defended from frost. And lastly, the moisture would injure them many ways; first by its contributing to destroy their vegetable life; secondly in promoting the chemical process of putrefaction; and thirdly by its encouraging the growth of mucedo, or mould, which will grow in moist situations without much light or air.

Too great warmth destroys both animal and vegetable life by stimulating their vessels into too great activity for a time, whence a subsequent torpor from the too great previous expenditure of the living power, which terminates in death. After the death of the organization a boiling heat coagulates the mucilaginous fluids, and if continued would I believe prevent the chemical fermentation of them; and that thus both vegetable and animal substances might be preserved. The experiment is difficult to try, and could not therefore be of much practical utility if it should succeed.

Great cold on the contrary destroys both animals and vegetables by the torpor occasioned by the defect of stimulus, and a consequent temporary death. Afterwards if a great degree of cold be continued, in some cases the expansion of their freezing juices may burst the vegetable vessels, and thus render the life of them irrecoverable. But there is another curious thing happens to many aqueous solutions, or
diffusions,

diffusions, which is, that at the time of congelation the dissolved or diffused particles are pushed from the ice, either to the centre, if the cold be applied equally on all sides, or into various cells, as mentioned in Sect. XIII. 2. 2.

This exclusion of salt is seen in freezing any saline solution in water; as common salt or blue vitriol exposed to severe frost in a two-ounce phial are driven to the center of it. Wine, vinegar, and even milk, may be thus deprived of much of their water. Very moist clay, when exposed to frosty air, shrinks and becomes much more solid according to the assertion of Mr. Kirwan. Mineralog. Vol. I. p. 9, the freezing water covering its surface with ice, and driving the molecules of clay nearer the centre. And lastly, the mucilage produced by boiling wheat flour in water, like book-binders paste, if not too thick, loses its cohesion by being frozen, the water driving, as it freezes, the starch from its crystallization; and from this circumstance probably is occasioned the change of flavour of apples, potatoes, and other vegetables, on being thawed after they have been frozen.

It is nevertheless affirmed, I think, by Mons. Reaumeur, that if frozen apples be dipped in cold water repeatedly, and the ice thus formed on their surface be wiped off, or if they be left in a large pail full of very cold water, so that they may not thaw too hastily, they will not lose their flavour. If this be true, and the apples will keep sound some time afterwards, it would seem that the vegetable life was not destroyed; but that, like sleeping insects, they were reanimated by the warmth; otherwise, if the flavour be not destroyed, and they could be immediately eaten or used in cookery, it is still a valuable discovery if true, and might lead us to preserve variety of fruits in ice-houses, as strawberries, currants, grapes, and pines, to the great advantage of society. See Sect. XVII. 2. 4.

As the process of fermentation will not commence or continue, I believe, in the heat of boiling water, or 212; and as this degree of heat can be easily preserved by steam, or by the vicinity of vessels

containing boiling water; it is probable, that fruits for the use of cookery might be thus preserved throughout the year, as the pulp of boiled apples, gooseberries, &c. put into bottles, and placed so as to be exposed to the wasted steam of steam-engines, or immersed in the hot water, which flows from the condensing of it; or near the boilers fixed behind some kitchen fires; as I suspect, that if such a degree of heat could be applied once a day, it would counteract the tendency to fermentation.

2. Another method of preserving some fruits is by gathering them during their acid state, before that acid juice is converted into sugar, as lemons, oranges, gooseberries, pears, and some apples; and if a part of the water be evaporated by a boiling heat so as to leave the acidity more concentrated, it is less liable to ferment, and in consequence will be longer preserved. For this purpose the fruit should be kept in a cellar, and corked in bottles, so as to be precluded from the changes of air, and variations of heat; gooseberries, and rhubarb-stalks, are thus successfully preserved for winter use; and if a tea spoonful of brandy be put into each quart bottle, it will prevent the growth of mucor or mould upon them.

3. As sugar will not pass into fermentation unless diluted with much water, and less so in low degrees of heat, many fruits may be thus preserved by impregnating them with sugar, and the better if they are kept in a dry cellar. Dr. Hales found that by inverting the end of a branch of a tree into a bottle of brandy for a few hours, that the whole branch died; hence it is usual and useful to cover preserved fruits with a paper moistened with vinous spirit, which prevents the growth of mucor or mould upon their surfaces, which is a vegetable thus easily killed by the intoxicating stimulus.

If sweet fruits be dried by heat, not only the superfluous water becomes exhaled, but the saccharine process is also promoted; and much of the mucilaginous or acid particles are converted into sugar, as in baking pears, or in drying figs, dates, raisins, apricots; so that

by gradually drying them many fruits may be well preserved, and require afterwards simply to be kept dry.

4. Some fruits, as the olive, are preserved in their unripe state in salt and water; the unripe pods of kidney-beans, and the hats of mushrooms, may be thus also kept for months in weak brine in a cool cellar enclosed in bottles without much change. But the oily kernels of nuts are well preserved in cellars beneath the soil to preclude the variations of heat, and covered in jars to prevent their evaporation. Other fruits are converted into pickles and preserved in vinegar, but lose their flavour; and others by being immersed in vinous spirit are preserved, as cherries, and thus transmuted from food to poison. And when the kernels of apricots, cherries, or bitter almonds, are preserved in brandy, which is called ratafia, we possess a mixture of two of the most poisonous productions of the vegetable kingdom; except perhaps the leaves of lauro-cerasus distilled in alcohol, which was sold as ratafia in Dublin, and produced many sudden deaths in the gin-shops.

v. The following lines are inserted to amuse the reader, and to imprint some of the foregoing doctrine on his memory.

ART OF PRUNING WALL-TREES.

BEHEAD new-grafted trees in spring,
Ere the first cuckoo tries to sing;
But leave four swelling buds to grow
With wide-diverging arms below;
Or fix one central trunk erect,
And on each side its boughs deflect.

In summer hours from fertile stems
Rub off the supernumerous gems;
But where unfruitful branches rise
In proud luxuriance to the skies,

Expect

Expect the exuberant growths, or bind
A wiry ringlet round the rind;
Or seize with shreds the leafy birth,
And bend it parallel to earth.

When from their winter-lodge escape
The swelling fig, or clustering grape;
Pinch off the summit-shoots, that rise,
Two joints above the fertile eyes;
But when with branches wide and tall
The vine shall crowd your trellis'd wall;
Or when from strong external roots
Each rafter owns three vigorous shoots;
Watch, and as grows the ascending wood,
Lop at two joints each lateral bud.
So shall each eye a cluster bear
To charm the next succeeding year;
And, as the spiral tendrils cling,
Deck with festoons the brow of spring.

But when the wintry cold prevails,
Attend with chisel, knife, and nails;
Of pears, plums, cherries, apples, figs,
Stretch at full length the tender twigs;
Vine, nectarine, apricot, and peach,
Cut off one third or half of each;
And, as each widening branch extends,
Leave a full span between the ends.

Where crowded growths less space allow,
Close lop them from the parent bough;
But when they rise too weak or few,
Prune out old wood, and train in new.
So, as each tree your wall receives,
Fair fruits shall blush amid the leaves.

ART OF PRUNING MELONS AND CUCUMBERS.

WHEN melon, cucumber, and gourd,
Their two first rougher leaves afford,
Ere yet these second leaves advance
Wide as your nail their green expanse;
Arm'd with fine knife, or scissars good,
Bisect or clip the central bud;
Whence many a lateral branch instead
Shall rise like hydra's fabled head.

When the fair belles in gaudy rows
Salute their vegetable beaux;
And, as they lose their virgin bloom,
Shew, ere it swells, the pregnant womb;
Lop, as each crowded branch extends,
The barren flowers, and leafy ends.
So with sharp stings the bee-swarm drives
Their useless drones from autumn hives.

But if in frames your flowers confin'd
Feel not one breezy breath of wind,
Seek the tall males, and bend in air
Their distant lovers to the fair;
Or pluck with fingers nice, and shed
The genial pollen o'er their bed.
So shall each happier plant unfold
Prolific germs, and fruits of gold.

S E C T. XVI.

THE PRODUCTION OF SEEDS.

- I.** To produce seeds early. 1. Sow before winter, or in warm situations. 2. Transplant the roots. 3. Cut off superfluous shoots. 4. Give less water. **II.** To produce seeds in great quantity. 1. Sow early, or when the seed ripens. 2. Transplant the roots deeper, or earth them up. Horse-hoe and hand-hoe. Improved drill husbandry. Dibbling. Corn lands laid level. Egyptian wheat with branching ears. 3. Destroy the central shoot. Eat down wheat and roll it. This is sometimes injurious. 4. Pinch off useless summits of beans. Eat down too vigorous wheat. 5. Roll it to lessen the straw. 6. Give less water. **III.** To ripen seeds. 1. Warmth and dryness. 2. Frosty nights. 3. Lime forwards the ripening of seeds. 4. Cut off bulbs and root-suckers of orbis. *Helianthus tuberosus*. *Rheum palmatum*. **IV.** To generate best kinds of seeds. Choose early plants insulated from others. Impregnate the stigmas of some with the anther-dust of others. Whence peas may be produced of different colours. **V.** To collect good seeds. Change of seeds is useless, unless for better kinds. Choose the earliest seeds. Pick out the largest potatoes for planting, and the best radishes for seed, and the earliest ears of wheat. **VI.** To determine the goodness of seeds. Weigh a measure of them. Cast them into salt water. Beans more economical than oats as provender. Seeds continue to improve during the water-months. **VII.** To preserve seeds. 1. Collect before they shed naturally. Dry them before they are stacked. Gluten of wheat destroyed by fermentation. Make the corn-stack highest in the middle. The great durability of seeds. Keep them dry. Not in contact with walls. Convenient oat-boxes for stables. Wheat dried on a malt-kiln to preserve it. 2. Ventilation prevents mould. 3. Seclude them from heat, beneath the soil. In ice-houses. 4. Magazines of grain suffered to vegetate at top. Covetous farmers. 5. New and old seeds. 6. Preserve seeds in sugar, or in charcoal, for long voyages. And flesh-meat in treacle. **VIII.** To sow seeds advantageously.
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Native seeds, foreign ones. Sow soon after the ground is turned over, and early in the spring, in the autumn. 2. Economy of sowing three kinds of grass-seeds, and two kinds of wheat. Kinds of soil. 3. Mix sand or soil with some seeds. Soak them in water, salt and water, lime. Steep barley in dunghill water. Wood-ashes. Sow wet as well as dry. 4. Bury the fruit with the seed. 5. Wash the seeds of too luxuriant plants. Sow them early. IX. Question concerning general enclosure. Cain and Abel.

MANY of the circumstances above related concerning the production and enlargement of fruit are applicable to the production of the seeds, which are included in them; but those seeds, which contribute most to the nourishment of mankind, many of which are the progeny of annual or biennial plants, require other modes of cultivation.

As an introduction to this section it may be observed, how much more ingenuity was required in the discovery of nourishing mankind by the small seeds of the grasses, which have probably been since much enlarged by perpetual cultivation, than by the large roots of potatoes. The Isis or Osiris of Egypt seems to have invented the process of cultivating wheat, as well as flax, on the banks of the Nile; and afterwards Ceres and Triptolemus to have taught the former of these important discoveries all over the known world. While in later ages the Incas or Motezumas of Peru and Mexico seem to have destroyed the cannibals, or men-eaters, of that continent, and to have discovered and taught their people to support themselves by the cultivation of potatoes.

I. I. *To produce seeds early in the season.*

Those plants, which are required to yield a forward crop, as the peas and beans of our gardens, and those which our cold and short summers will not otherwise perfectly ripen, as wheat, should be sowed before the commencement of winter, either in natural ground, as in the

cultivation of wheat, or in situations sheltered from the north-east, as in the garden cultivation of peas and beans; or they may be sowed very thick in hot-houses, or under hot-bed frames, or under warm walls, and be transplanted, when they are one or two inches high, into the natural ground at due distances, when the weather is milder, and the plants are become hardier or less liable to be destroyed from their having longer acquired the habits of life.

When young plants of any kind are transplanted, the ground should be recently dug, as their expeditious growth depends so much on the atmospheric air being buried in the pores or interstices of the earth by the production of carbonic and nitrous acids, and ammonia, and heat.

The same advantage occurs by soaking seeds in water, or in the drainage from manure heaps, till they are ready to sprout, and then sowing them in a soil lately turned over; as their roots will then immediately put out by the newly generated heat, and newly produced carbonic acid in its fluid not its gaseous state.

2. The transplanting of young roots, if they be set no deeper than before, does not, I suppose, multiply the number of stems, as occurs when wheat is transplanted so deep as to cover the second joint; but by tearing off several small extremities of the roots, the new production of many viviparous buds is prevented, and that of oviparous buds increased in consequence, for reasons mentioned in No. 2. 4. of the preceding Section.

When the roots of wheat are transplanted and divided, not only a great increase of the crop is produced, but I believe the seed is likewise ripened earlier, as is asserted by Mr. Bogle. Bath Society, Vol. III. p. 494. And it is well known to gardeners, that transplanting garden-beans forwards them in respect to time, but shortens the height of the stem. Hence transplanted vegetables grow less in height, as transplanted beans, and less branchy, as transplanted melons, but produce and ripen their seeds earlier; which is a great advantage in
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the short summers of this climate; and if the roots can be divided, as in wheat, or new scions can be produced by their being transplanted deeper, as also occurs in wheat, the quantity of the seed may also be wonderfully increased by transplanting. See Sect. XII. 6.

3. Another mode of forwarding the production of seeds, and of sooner ripening them, consists in pruning off the viviparous tops or lateral shoots, which will bear no seeds at all, or only small or imperfect ones, in our northern summers. For this purpose the cutting away the tops of beans and of peas, and the lateral branches of artichokes, after the fruit-buds are formed, both forwards and enlarges the flowers and seeds, which remain, as more nourishment is derived to them.

4. As a superfluous supply of water is more friendly to the production of leaf-buds than to the generation of flower-buds, to derive less water than usual to the roots, forwards the production of seeds, a fact well known in the gardens of warmer climates, which are perpetually watered from reservoirs or wheel-engines. But when the blossoms appear, an addition of water must forward their growth by supplying nourishment, which should again be lessened when the fruit has acquired its full size, both to expedite its ripening, and to increase its flavour; as the saccharine matter and essential oil will be less diluted with water.

In the dry summer of 1799 I had the opportunity of flooding some rows of beans in my garden, which by being done too frequently, or too copiously, occasioned them to grow to a much greater height than usual, and in consequence to bring to perfection few seeds, and some of them none. As I suppose the new shoots of fig-trees in the beginning of summer occasions the first production of young figs to fall off from the want of that nourishment, which is now expended in the growth of new leaf-buds. See Sect. XV. 3. 4. Whence the facility of producing leaf-buds seems evidently to prevent the genera-

tion of flower-buds, and the use of cutting off the summits of tall beans is thus explained, as directed above.

II. 1. *To produce seeds in great quantity* from annual or biennial plants they should be brought forward in respect to the season in our northern summers; that a greater quantity of viviparous buds may arrive early at their maturity for the purpose of generating oviparous buds soon enough in the summer to ripen their seeds; on this account those should be sown in the autumn which will bear the severity of the winter.

Nevertheless the seeds of those plants, which are natives of this climate, should probably be sowed at the time they become perfectly ripe, as occurs to them in their natural state; that is, either when the seed is shed upon the ground by the parent plant, or when the fruit or husk, which encloses it, becomes naturally ripe after it has fallen on the ground. Thus I have seen crabs covered with leaves in hedge-bottoms, which have not decayed till the early spring. Many pears do not become ripe in our store-rooms till March or April; and ivy berries and holly berries hang on their respective trees till the vernal months, and are not till that time eaten by the thrushes. Hence it is probable, that the seeds in these durable fruits or berries continue to ripen, or to become more mature, and prepared for their future growth during the winter months.

2. It was shewn in Sect. IX. 3. 7. that when wheat was transplanted so deep as to immerse the first joint above the root into the soil, many new stems would shoot up and strike their roots into the earth; and that thus four or six new plants, or more, would be generated by the caudex of the leaf-bud, which constitutes that joint. This mode of transplantation therefore will much increase the quantity of the crop of seed, if it can be done soon enough for these additional stems to ripen their corn, before the summer ends.

There is another mode of increasing this product of additional
stems

stems without transplantation, which consists in sowing the wheat in rows by what is called a drill-plough according to Mr. Tull's method; and when the first stems rise a few inches high, a horse-hoe, made like a very small plough, is to be brought so near each row, as to turn up some earth against the stems, so as to cover the first joint above the root with soil; whence new stems will be generated, and shoot up round the old one; and thus increase the crop in the same manner as by deep transplantation.

The theory of Mr. Tull's drill husbandry is explained in Sect. IX. 3. 7. and in XII. 5. which is of late years supposed to have been improved by introducing the hand-hoe in place of the horse-hoe, and thus giving an opportunity of sowing the rows or drills nearer together, as will be seen by the following method, now introduced into almost general use in Norfolk by Mr. Coke; though Mr. Tull himself much prefers the horse-hoe as turning over the earth much deeper than the hand-hoe, and thus rendering that part of it more exposed to the air, which was before more deeply secluded from it; and also rendering it more pervious to vegetable roots; to which may be added, that both kinds of hoeing render the surface more permeable to the rains and dews, and prevent the cracks in dry weather; which are very injurious to the roots of plants; both which advantages depend on the porosity of the soil, which must extend deeper by the use of the horse-hoe than the hand-hoe.

Mr. Tull makes other ingenious remarks on the use of horse-hoeing. In the beginning of winter, when the wheat has obtained one blade like grass, or two or three leaves, the horse-hoe is brought near the rows and deep, and the earth turned from them so as to form a ridge between them. By this ridge in level grounds he thinks the rows are shaded from the cold winds in some situations, and that the roots of the wheat are kept drier, and thence less injured by frosts. In the spring this ridge in the intervals between the rows is divided by the horse-hoe, and turned back against the rows of corn after it
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has been fertilized by the air and rains, and dews of winter. See Tull's Husbandry, Ch. IX. and Sect. XII. 5. of this work.

Mr. Coke of Holkham in Norfolk assured me, that in thirteen years experience on a farm of 3000 acres he had found the drill husbandry in that country greatly superior to sowing seeds of all sorts by the hand in what is termed the broad-cast method, but differs in the number and arrangement of his rows from the method of Mr. Tull in the following circumstances.

Mr. Tull drilled two rows of seed a few inches from each other, and then left a space of two or three feet, and then drilled two more rows near each other, for the purpose of passing a hoe between each double row drawn by a horse, which was therefore termed a horse-hoe; but Mr. Coke drills all his rows of wheat and of peas nine inches from each other, and those of barley six inches and three quarters from each other; this is performed by a drill plough made by the Rev. Mr. Cook, which drills six rows at a time, and thus sows an acre of land in an hour, and is drawn by a single horse; and the quantity of seed consumed is about six or seven pecks to an acre, which is about half what is used in the sowing by the hand in the broad-cast method.

Early in March Mr. Coke uses the hand-hoe, which for hoeing the rows of wheat and of peas is about six inches wide, and for hoeing those of barley about four inches wide. By this hoe the surface is not only turned over, and the weeds between the rows rooted up, but it is also accumulated about the roots of the growing corn, and covers and consequently destroys the low growth of poppies amongst them; which are a very frequent weed in that part of the country. A second hoeing is performed about the middle of May, and the soil is again not only cleared from weeds but accumulated against the rising corn, each of which hoeings cost about twenty-pence an acre.

Nevertheless I am informed, that some attentive agricultors use the horse-hoe belonging to Mr. Cook's drill-machine, though the rows
of

of corn are but nine inches from each other ; and assert, that this occasional trampling of the horse on the young plants is of no very ill consequence, a circumstance well worth observing, as it removes the principal disadvantage of the horse-hoe, which consists in the too great distance of the alternate rows of the corn-plants.

By the earth being thus accumulated against the roots of the corn it is said to tiller or tellure much ; that is, to throw out four or six stems, or more, around the original stem, and thus to increase the number of ears like transplanting the roots, insomuch that Mr. Coke obtains by this method between four and five quarters of wheat on every acre, which in the broad-cast method of sowing did not yield more than three quarters on an acre, beside saving a strike and half of the seed corn, unnecessarily consumed in the broad-cast method of sowing. To this should be added another advantage, that as the land is thus kept clear from weeds, and has its surface twice turned over, and thus exposed to the air, it is found to save one ploughing for the purpose of a succeeding crop of turnips.

It is probable, that one hand-hoeing in the beginning of winter, so managed as to turn the soil from the roots of the corn, and to leave it rather elevated between the rows, as Mr. Tull recommends to be performed by his horse-hoe, might give a similar advantage to this mode of cultivation ; and also if another hand-hoeing was applied, as soon as the wheat is out of blossom, to supply more nourishment to the young seed might increase its plumpness and weight, as mentioned in No. 2. 3. of this Section.

The lands thus managed by Mr. Coke are laid level, and not in ridges and furrows, and can thus be ploughed crosswise ; and the crop is equally good throughout the whole ; whereas in the furrows of some lands it is less forward or less prolific than on the ridges ; whence much light corn is mixed with the good, which is obliged to be separated from that, which is marketable, and used for hogs or poultry. Add to this, that in this mode of husbandry the straw is believed

lieved to be larger and in greater quantity as well as the grain, and the land to be less impoverished, as no weeds are suffered to grow on it, and as its surface is so frequently turned over, and exposed to the air.

In China the corn lands are laid on a level, not in ridges and furrows; which is supposed to be the most advantageous plan in almost every situation, which is proper for the cultivation of corn, as by being thus rendered capable of being divided by cross-ploughing, almost any kind of soil may be rendered more proper for the use of the drill husbandry, by which it is seen in the above account of the Norfolk management, that twelve strikes more of wheat are raised on an acre, and one strike and a half saved in the consumption of seed-wheat, which at six shillings a strike arises to a considerable sum on a large farm.

Nevertheless there seem to be many advantages attending the forming the surface of land into ridges and furrows; in wet lands with a substratum of clay the furrows are convenient channels to carry off the water, where there is a sufficient declivity, as treated of by Mr. Tull in his *Horse-hoeing Husbandry*, Ch. XVI. Add to this, that in some situations a deeper stratum of the soil, where it is valuable, may be occasionally turned up, and exposed to the air, and to the roots of vegetables, by gradually changing the locality of the ridges; and lastly, in every situation a greater surface both of the soil, and of the summits of the stems, or ears, are exposed to the influence of the air by means of ridges and furrows; for as the plants of wheat are but three or four feet high, the surface of a crop of wheat is increased as well as the surface of the ground it grows upon, and not as the base on which the declivities or hills rest, as some have erroneously supposed. See Sect. X. 3. 8.

There is another method of sowing wheat in rows used in some counties, which is termed dibbling in the language of agricultors, and consists in making perpendicular holes one inch and half or two inches

inches deep, as is commonly done in planting potato-roots; these holes are made by a man, who has a proper staff shod with iron in each hand, and as he walks backwards is able by looking at the part of the row already made to keep nearly in a straight line, and to make two holes at once at about nine inches distant from each other every way. Two or more children attend the man, and drop two, or three, or four seeds into each perpendicular hole, which are afterwards covered by drawing over them what is called a bush-harrow.

This method by sowing the wheat in rows adapts it for the use of the hand-hoe, as by sowing it by a drill machine, but must be attended with greater expence, and I suspect with less accuracy of the distribution of the seed, owing to the hurry or fatigue of the children employed; and I also suspect that sowing in drills is preferable, because a greater quantity of earth is turned over, and much air in consequence included in its interstices; whereas in making perpendicular holes the sides of the holes are compressed, and rendered more solid; whence potato-roots also might probably be more advantageously planted by making drills instead of perpendicular holes.

A correspondent of the board of agriculture asserts, that on looking over a field of potatoes near Leicester, which had all been planted at the same time, and on land equally manured, he observed a great difference of the growth of one part of the field, which on inquiry he found to have been owing to the roots having been planted in drills, where the plants were so much stronger; and by a setting stick in holes, where they were so much less vigorous; English Encyclopedia, Art. Husbandry, p. 483: which difference of growth I suppose to have been owing to the circumstances above mentioned.

A few ears of wheat were lately given me, which were branched, having four or five less ears growing out of each side of the principal ear; it was procured at Liverpool, and was called Egyptian wheat, or Smyrna wheat. It is described in the Supplem. Plantarum of the

younger Linneus, as well as in the species *Plantarum* of the elder; and is said to be a native of Egypt, and to be cultivated at Naples; it is called “*triticum compositum*, or wheat with a compound ear, crowded with less ears, awned; and is said to be related to *triticum æstivum*, summer wheat; but the spike is four times larger, a hand in length, composed of less spikes, two faced, alternate, approximated, from nine to twelve, the lower ones being shorter, and the top one solitary.” *Suppl. Plant.* p. 115.

The plant, which was given me, had five tall and thick stems from one root, but seemed to have been plucked up before it was quite ripe, whence I cannot judge of the size of the grain, but should imagine, that it is a species well worthy of attention. The few ears, which I possessed, were sown in the spring of this year, 1799, not having obtained them soon enough to sow in the autumn. When they were an inch or two high, they were transplanted into a moistish part of my garden; and though the year has been uncommonly cold and wet, and a great part of the autumn-sown wheat of this country is blown down upon the ground, and is not yet ripe, yet almost every root of the Egyptian wheat has from ten to twelve stems, and stands upright on strong straw about three and a half, or four feet high. The best stems have one principal ear about five inches long, with five or six shorter ones branching out on each side of it. They begin to appear brown, and I hope will ripen. I have since found that this species of wheat is mentioned in Tull’s *Husbandry* under the name of *Smyrna wheat*. He adds that it is highly productive, but on that account requires a good soil.

3. Another method of promoting the growth of lateral stems consists in destroying the central shoot; when this is done, other new stems arise from the joint immediately above the root, which in wheat is in contact with the earth. On this account, when wheat plants are sufficiently forward in respect to the season, it is thought to be advantageous to eat the first stem down by sheep to increase the quantity

quantity of the subsequent crop. See Sect. IX. 3. 7. It should be nevertheless observed here, that the trampling of the sheep on lands, which are not too adhesive, will press down the first or second joint into the earth, and thus assist the production of many side shoots. But in very adhesive soils this trampling of the stems into the ground may be injurious. See a paper in Bath Agriculture, Vol. I. Art. XV. In soils which are not too adhesive, when the crop appears thin, it is probable, that a roller drawn over it by pressing the first or second joint into the soil, might promote the production of side shoots, or make them tiller, or tellure, in the language of agricultors. And when grass or clover seeds are designed to be sown on the wheat-land, it might first be harrowed, and then either rolled or trampled by the sheep, which eat it; either or both of which might press down the root-stems of the corn, and cover the newly sown clover-seeds with soil.

This mode of eating down forward wheat with sheep is analogous to cutting off the central buds of melons and cucumbers to make them produce earlier fruit, and in this climate perhaps in greater quantity; as those produced after the great extent and elongation of the central branches would be too late to ripen in this climate: and by their exuberant generation of a viviparous progeny would retard the succession of lateral shoots, and a consequent quicker production of flowers.

Nevertheless where the crop is not too luxuriant or too forward, the eating down the first stem by sheep may be an injurious practice; as Mr. Tull thinks, that by thus destroying the first stem, the ears of the later ones have not time to ripen, and thence become light in respect to the size or plumpness of the grain; and that these secondary stems become weak, and are liable to fall down, both which he says commonly occur where the crops are eaten by sheep.

Mr. Tull, whose work is throughout a great effort of human genius, adds a very wise axiom, " that it is most advantageous to hasten,

what we can, the time of blossoming; and to protract the time of ripening." Horse-hoeing Husbandry, Ch. XI. p. 147; for it is the farinaceous reservoir of nutriment laid up in the cotyledon of the new seed for the future growth of the corculum or new embryo, for which we cultivate the plant; and this reservoir is formed between the blossoming and ripening of the grain, either before or after the impregnation of the pericarp, or seed-vessels, and thus renders the grain plump and heavy. Mr. Tull in another part of his work recommends an additional horse-hoeing immediately after the blossom is over, to supply more nutriment to the ripening grain. Ch. IX. p. 120. Mr. Tull esteems the eating down of wheat by sheep to be generally a very injurious practice in this climate, by rendering the ears light and the straw weak; by retarding the time of blossoming, as well as the growth of the stems.

4. In the moist springs of this climate many annual or biennial plants are liable to shoot out too many or too strong viviparous branches, which can not generate flower-buds soon enough to ripen their seeds in our cold and short summers. This always happens to cucumbers and melons, which were brought from warmer countries, and to the peas and beans of our gardens, and sometimes to corn-plants, which are liable in wet seasons to produce too strong stems and foliage, which have not time to generate the flower-bud at their summit soon enough to perfect and to ripen the seed. Melons and cucumbers have been mentioned in Sect. XV. 2. 5. and in respect to garden beans their viviparous tops should be pinched off, which if not too old may be eaten as an agreeable vegetable, when well boiled; and thus more nutriment is derived to the oviparous buds beneath, which renders them larger, and perhaps more numerous. To prevent field peas from running into straw in moist soils less manure should be used; and field beans may have their tops cut off by a scythe fixed into a straight shaft.

Annual cotton plants are much cultivated in some colder parts of
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the Chinese empire, and the cultivators lop off the tops to increase the number of pods, and to hasten their production; and in the West Indies the flowers of the rose tree are believed to be accelerated and increased by topping the branches. Embassay to China by sir G. Staunton, Vol. III. p. 202. 8vo. edit.

When the stems and foliage of wheat are thus too vigorous, it may be advantageous to eat it down by sheep as above mentioned; which may not only destroy the too vigorous viviparous central stems, but also produce a greater number of lateral ones; which may sooner terminate in oviparous ones, so as to produce more grain with less straw.

5. It is also probable, that rolling them as mentioned above, if it be done in a morning before the dew is off, might so far bruise the stems and roots, as to stop their too great propensity to nourish the viviparous buds, and in consequence to favour the growth of the oviparous buds on their summits; which might forward the harvest season, as well as increase the product of grain in proportion to the quantity of straw. From rolling wheat in spring on fields where the surface remains uneven or cloddy, another advantage may be derived, by breaking the clods or eminences, and thus earthing up many of the stems above the second joint, and thus inducing a new set of root-scions to put forth, or tiller. See Sect. XII. 3.

6. The garden plants, which are too vigorous, in situations where there is a command of water, as in the gardens of warm climates, should have less water derived to them, till the blossoms appear; because a greater quantity of moisture facilitates the production of viviparous buds so much as to retard that of oviparous ones, and thus diminishes the quantity as well as retards the ripening of the crop. But in these situations, as soon as the blossoms appear, a greater supply of water should be allowed, which will contribute to nourish and enlarge them, as mentioned above; as is practised in some countries of the east, where they do not flood their rice-grounds, till they are in flower.

flower. See Sect. XV. 3. 4. But less water is again required, when the seed has arrived at its full size, as before spoken of.

III. 1. *To forward the ripening of seeds.* A due degree of warmth and of dryness seems to include the circumstances principally required. The warmth not only accelerates the various secretions of vegetables by increasing their irritability and consequent activity, but, after the mucilaginous, starchy, saccharine, and oily matters are secreted into proper reservoirs, may contribute perhaps chemically to their change into each other, or to their greater perfection. And the dryness of the air, whether hot or cold, is necessary to give perfect ripeness to seeds; as otherwise the due exhalation of the aqueous parts of the secreted fluids, which form the nutritive parts of seeds, does not properly proceed; and the seed gathered in this condition is liable to mildew in the barn or granary, or to become shrivelled and wrinkled, as it dries.

2. It is believed in Scotland, that even the frosty nights of autumn contribute to ripen the late crops in that inclement climate, which some have ascribed to the moonlight, but, which I have indeed suspected, that the frost may in some measure effect by converting the mucilage of the grain sooner into starch. This I was induced to imagine by having observed that bookbinder's paste, made by boiling wheat-flour in water, lost its adhesion after having been frozen; and also from a culinary observation, that when ice or snow is mingled with flour instead of water in making pancakes, that it much improves them; the truth of which I have heard boldly asserted, but never witnessed the experiment. See Sect. VI. 3. 3.

There is nevertheless an experiment related by Dr. Roebuck in the Edinburgh Transactions, Vol. I. which seems to shew, that the grains of oats continue to fill and to become heavier even during the autumnal frosts; which may probably occur during the sunshine of the middle part of the day, as occurs in the vernal frosts of this part of the country. In 1780 near Borrowstones the oats were green
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even in October, when the ice was three fourths of an inch thick. He selected several stalks of oats of nearly equal fulness, cut half of them, and marked the remainder, which continued fourteen days longer in the field; after being dry, the grains of each parcel were weighed; and eleven of those grains, which had remained in the field, weighed thirty of those which had been cut a fortnight sooner.

This important experiment should teach our farmers not to cut their peas and beans too early in inclement autumns; which are so frequently seen to become shrunk and shrivelled in the barn or granary, and inclined to rot from deficient ripeness, and consequent softness or moisture; and thus contain much less flour in proportion to the husk or bran.

3. The wheat produced after land has been much limed, is believed to be thinner skinned, and to yield more good meal, than other wheat, and to make better bread. See Sect. X. 6. 7. On this account I suppose one use of lime is to forward the ripening of seeds by converting their mucilage sooner into starch or oil; as according to the experiments of M. Parmentier the goodness of bread depends much on the quantity of starch contained in it; who found, that if the starch taken from eight pounds of raw potatoes, by grating them into cold water, was mixed with eight pounds of boiled potatoes, as good bread might be produced as from wheat flour. See Sect. VI. 3.

4. The seeds of some plants, which also propagate themselves by bulbs at their roots, will not ripen in this climate naturally, as the orchis; but are said to ripen, if the new bulb be cut off early in the season; or if the propagation by their roots be retarded or prevented by confining them in garden-pots, as the lily of the valley; and it is probable, that the seeds of potatoes might be rendered more perfectly ripe, and in consequence better for the cultivation of new varieties; if the young roots were taken away early in the season from that, which is to bear seed; or if they were confined in garden pots.

If the orchis could by these means be cultivated from seed on moist meadows or morasses, it might become a profitable article of husbandry ; as when it is scalded in boiling water, and the peel rubbed off, it is sold by the name of falep, and might become a nutritive article of diet, like sago and vermicelli, if it could be propagated at less expence.

It is also probable, that Jerusalem, or ground artichokes, helianthus tuberosus, might be induced to ripen its seeds in this country, if the new roots from a few of the forwardest plants were taken away early in the season, or if they were confined in garden pots. And if this plant could be propagated by seed, it might make an useful product in agriculture, as horses are very fond of the leaves, and swine of the roots ; both of which are produced in great quantity ; and as the latter contain much sugar, they must be very nutritive ; and in respect to their culinary use are remarkably grateful to moist palates, as well as nutritive, when cut into slices, and baked in beef or mutton pies ; but are said to be flatulent in the bowels of those whose digestion is not very powerful ; a property which might be worthy attention, where the propensity to fermentation is required, as in making bread with potatoes, or in the distillery.

It is also probable, that if the large new root-suckers of other perennial plants, which do not bear bulbous or tuberous roots, and which are late in ripening their seeds, or do not ripen them perfectly in this climate, were cut or torn off early in the season, as of the rheum palmatum, palmated rhubarb, or rheum hybridum, mule rhubarb ; or if their roots were confined in garden-pots, that they might be more liable completely to ripen their respective seeds. See Sect. XV. 2. 4.

IV. 1. *To generate the best kinds of seeds* the most healthy plants must be chosen, and those which are most early in respect to the season ; these should be so insulated, as to have no weak plants of the same species, or even genus, in their vicinity, lest the fecundating

dust of weaker plants should be blown by the winds upon the stigmata of the stronger, and thus produce a less vigorous progeny.

Where new varieties are required, the male dust of one good variety, as of the nonpareil apple, should be shed upon the stigmas of another good variety, as of the golden-pippin; and it is probable some new excellent variety might be thus generated.

Mr. Knight has given a curious experiment of his impregnating the stigmas of the pea-blossoms of one variety with the farina of another. He says, *Treatise of Apple and Pear*, p. 42, “ Blossoms of a small white garden-pea, in which the males had previously been destroyed, were impregnated with the farina of a large clay-coloured kind with purple blossoms. The produce of the seeds thus obtained were of a dark grey colour, but these having no fixed habits, were soon changed by cultivation into a numerous variety of very large and extremely luxuriant white ones; which were not only much larger and more productive than the original white ones, but the number of seeds in each pod was increased from seven or eight to eight or nine, and not unfrequently to ten. The newly made grey kinds I found were easily made white again by impregnating their blossoms with the farina of another white kind. In this experiment the seeds, which grew towards the point of the pod, and were by position first exposed to the action of the male, would sometimes produce seeds like it in colour, whilst those at the other end would follow the female.

“ In other instances the whole produce of the pod would take the colour of one or other of the parents; and I had once an instance in which two peas at one end of a pod produced white seeds like the male, two at the other end grey ones like the female, and the central seeds took the intermediate shade, a clay colour. Something very similar appears to take place in animals, which produce many young ones at a birth, when the male and female are of opposite colours. From some very imperfect experiments I have made, I am led to sus-

pect that considerable advantages would be found to arise from the use of new or regenerated varieties of wheat, and these are easily obtained, as this plant readily sports in varieties, whenever different kinds are sown together." See Sect. VII. 2. 6. of this work.

2. The white and blue peas sown in fields as well as in gardens sometimes possess the property of becoming soft by boiling, at other times not. This circumstance is said to depend on the nature of the soil, but has not yet been sufficiently investigated; perhaps the greater or less maturity of the peas at the time of reaping them may have more or less contributed to fill their fibrous cells or divisions with mucilage or starch. The greater or less mealiness produced by boiling potatoes seems to be an analogous circumstance, and is thought by some to arise from the nature of the soil rather than from the species or variety of the planted root.

The mealiness of some boiled potatoes, and the softness of some boiled peas, may occasionally be affected by the acidity of the spring water, in which they are boiled; but is generally I suppose owing to the mucilage of some of them being more or less coagulable by heat, than that of others. Something similar to which obtains in animal mucus, as the crystalline humour of the eyes of fish become hard and opaque by boiling; while the skins of animals, and the tendons of their feet, become a soft mucus or jelly by boiling; and some of the liquids, which are found in the cells or cavities of the body in dropsies, are observed to coagulate by heat, and others to become more fluid. The causes of this difference merits further inquiry.

V. 1. *To collect good seeds*, according to the observations of Mr. Cooper of Philadelphia, consists not in procuring new seeds from distant places, as is generally supposed, but in selecting the best seeds and roots of his own; which though he has continually sown or planted them in the same soil, every article of his produce is greatly superior to those of any other person, who supplies the market, and they seem still in a state of improvement. He believed that no kind of insect would

would degenerate the breeds of vegetables, and therefore adopted the plan of Mr. Bakewell in England in respect to quadrupeds, who continued to improve his flocks and herds by the marriages of those, in which the properties he wished to produce were most conspicuous without regard to consanguinity or incest.

Mr. Cooper was led to his present practice, which he began more than forty years ago, by observing that vegetables of all kinds were very subject to change with respect to their time of coming to maturity, and other properties, but that the best seeds never failed to produce the best plants. Among a great number of experiments he particularly mentions the following.

“ About the year 1746 his father procured seeds of the long watery squash, and though they have been used on the farm ever since that time without any change, they are at this time better than they were at the first.

“ His early peas were procured from London in the year 1756, and though they have been planted on the same place every season, they have been so far from degenerating, that they are preferable to what they were then. The seeds of his asparagus he had from New York in 1752, and though they have been planted in the same manner, the plants are greatly improved.

“ It is more particularly complained of, that potatoes degenerate, when they are planted from the same roots in the same place. At this Mr. Cooper says, he does not wonder, when it is customary with farmers to sell or consume the best, and to plant from the refuse; whereas having observed that some of his plants produced potatoes, that were larger, better shaped, and in greater abundance than others, he took his roots from them only; and the next season he found, that the produce was of a quality superior to any, that he had ever had before. This practice he still continues, and finds that he is abundantly rewarded for his trouble.

“ Mr. Cooper is also careful to sow the plants, from which he raises

his feed, at a considerable distance from any others. Thus, when his radishes are fit for use, he takes ten or twelve, that he most approves, and plants them at least one hundred yards from others, that blossom at the same time. In the same manner he treats all his other plants, varying the circumstances according to their nature.

“ About the year 1772 a friend of his sent him a few grains of a small kind of Indian corn, not larger than goose shot, which produced from eight to ten ears on a stalk. They were also small, and he found, that few of them ripened before the frost. Some of the largest and earliest he saved, and planted them between rows of a larger and earlier kind, and the produce was much improved. He then planted from those that had produced the greatest number of the largest ears, and that were the first ripe, and the next season the produce with respect to quality and quantity was preferable to any, that he had ever planted before.

“ The common method of saving feed-corn by taking the ears from the heap is attended, he says, with two disadvantages; one is the taking the largest ears, of which in general only one grows on a stalk, which lessens the produce; and the other is taking ears that ripen at different times.

“ Many years ago Mr. Cooper renewed all the seed of his winter grain from a single plant, which he had observed to be more productive, and of a better quality than the rest; which he is satisfied has been of great use. And he is of opinion, that all kinds of garden vegetables may be improved by the methods described above, particular care being taken that different kinds of the same vegetables do not bloom at the same time near together; since by this means they injure one another.” Communications to the Board of Agriculture, Vol. I. part 3. Letter from Dr. Priestley.

2. As the varieties of plants are believed to be produced by different soils and climates, which varieties will afterwards continue through many generations, even when the plants are removed to other soils and

and climates, it must be advantageous for the agricultor to inspect other crops as well as his own; and thus wherever he can find a superior vegetation to collect seeds from it; which is more certain to improve his crops than an indiscriminate change of feed.

But where feed-corn is purchased without a previous observation of its superior excellence, perhaps it would be more advantageous to take that from better kinds of soil, and from somewhat better climates; as the good habits acquired by such seeds may be continued long after their removal to inferior situations. And on the contrary, care should be taken not to collect a change of seeds from worse climates or inferior soils, unless the agricultor is previously certain that they are of a superior kind.

VI. 1. *To determine the goodness of seeds*; the weighing a given measure of them may generally be esteemed a criterion; as it is known, that when seeds are put into cold water, those which are less perfect are liable to swim, and the sound ones to sink; thus the imperfect seeds of rye-grass and of clover may be detected by throwing a spoonful of them into water; but the seeds of rye-grass are said to be frequently adulterated by a mixture of the seeds of twitch or dog's grass, which can only be discovered by an experienced eye. This even is said to be a test of the goodness of malt; as those grains, which are not perfectly germinated, will swim with one end upwards, I suppose the root end; and those which are perfectly germinated swim on their side, whilst the sound ungerminated barley sinks in water.

It is therefore a proper criterion of good feed-wheat to cast it into salt and water, just so saline as to float an egg; as the more salt is dissolved in the water, the heavier it becomes; and hence none but quite sound grains of wheat will sink in this brine; and that which swims is properly rejected. This rejection of the light grains by steeping wheat in brine is probably of greater consequence to the ensuing crop, than the adhesion of any salt to the grain, which has

been believed to destroy the eggs of insects supposed to adhere to it, or to fertilize the soil.

2. The weight of a given measure of corn will also with considerable certainty discover the quantity of husk or bran contained in it, compared to the quantity of flour; as that grain, which is cut too early, or which is otherwise not quite ripe, as happens in wet seasons, shrinks in the barn or granary, and becomes wrinkled, and has thus a greater proportion of skin or bran, than that which has been more perfectly ripened, and will hence weigh lighter in proportion.

A test of this kind may enable us to determine whether peas and beans, or oats, are preferable in respect to economy as provender for horses. A strike or bushel of oats weighs perhaps forty pounds, and a strike or bushel of peas and beans perhaps sixty pounds; and as the skin of peas and beans is much less in quantity than that of oats, I suppose there may be at least fifteen pounds of flour more in a strike of peas and beans than in a strike of oats. There is also reason to believe, that the flour of beans is more nutritive than that of oats, as appears in the fattening of hogs; whence according to the respective prices of these two articles I suspect, that peas and beans generally supply a cheaper provender for horses than oats, as well as for other domestic animals.

But as the flour of peas and beans is more oily, I believe, than that of oats, it may in general be somewhat more difficult of digestion; hence when a horse has taken a stomach full of peas and beans alone, he may be less active for an hour or two, as his strength will be more employed in the digestion of them, than when he has taken a stomach full of oats. According to the experiment of a German physician, who gave to two dogs, which had been kept a day fasting, a large quantity of flesh food; and then taking one of them into the fields hunted him with great activity for three or four hours, and left the other by the fire. An emetic was then given to each of them, and
the

the food of the sleeping dog was found perfectly digested, whilst that of the hunted one had undergone but little alteration.

Hence it may be found advisable to mix bran of wheat with the peas and beans, a food of less nutriment, but of easier digestion; or to let the horses eat before or after them the coarse tussocks of four grafs, which remain in moist pastures in the winter; or lastly, to mix finely cut straw with them.

3. Another way of distinguishing light corn from heavy is by winnowing; as the surface of the light grains being greater in proportion to their solid contents, they will be carried further by the current of air, which is produced by the van; though the heavy grains would roll further on the floor after rolling down a grate to separate the dust; because their vis inertia would carry them further, after they are put in motion; and their surfaces would be resisted by the air no more than those of the lighter grains.

4. Finally, there is reason to believe that a progressive improvement of many seeds exists during the warmer days of winter in our granaries, which probably consists in the process of the conversion of mucilage into starch; in the same manner as the harsh juices of crab-apples, and of austere pears, are continually changing into sugar during the winter; both which processes are probably in part chemical, like the slow but perpetual change of sugar into vinous spirit, when the juices of sweeter apples and pears, or grapes, are put into bottles in the manufacture of cyder, perry, and wine.

This improvement of wheat, and of barley, and of oats, is well known to the baker, the maltster, and the horse-dealer; as better bread is made from old wheat, and barley is converted into better malt in the vernal months; and horses are believed to thrive better, and to possess more vigour, when they are fed with old than with new oats.

VII. 1. *The preservation of seeds* next demands our attention. Those seeds which are liable to lie upon the ground, as peas and corn,

corn, when thrown down by stormy or wet seasons, should be gathered rather earlier; lest they should begin to germinate, as they lie upon the ground, and would hence become a kind of malt after drying. Other seeds should be gathered, before they would spontaneously fall from their pericarps, to prevent the loss which must otherwise ensue in the reaping, or mowing, and carrying them to the barn, which often amounts to as much as is necessary to sow the land, which produced it, as well as to supply the depredations of birds, insects, and vermin.

Monf. B. G. Sage accuses the farmers of some parts of France of collecting their wheat with many green weeds immediately after reaping it, and pressing it close together in their bars; by which the stack undergoes a fermentation with great heat like some hay-stacks; and that the corn is by this fermentation killed, and will not grow when sown like hay-seeds from a fermented hay-stack, mentioned in Sect. X. 11. 7; and also that the gluten, or vegeto-animal matter of the corn, is destroyed; and it on that account makes less agreeable and less wholesome bread; and lastly, that the straw is much injured by becoming mouldy. *Journal de Physique*, Sep. 1794.

Monf. B. G. Sage adds, that the following process will discover, whether wheat has been thus injured, which may be interesting both to the baker, and wheat-buyer, who wants it for seed-wheat. Make a paste with flour and water, then wash it with your hands under water, which must be frequently changed, till it no longer becomes discoloured. The substance remaining in the hands is the gluten; if the corn be good, this is elastic, and will contract when drawn out; if the corn has begun to heat, it is brittle; if the corn has fermented, none of the gluten will be obtained.

In this country, where corn is seldom cut too early, or pressed together on the stack, the principal circumstance required is to keep it dry; as the straw is not liable to ferment like new hay made with young grass, which contains sugar at every joint of the stem. To preserve

preserve a stack of wheat dry, a good cover of thatch may seem sufficient ; but as this is liable to injury by vermin, it would be an additional security, if at the time of making the stack the sheaves were laid highest in the middle, and lower on every side, so that if any wet should find its way into the stack, it might drain onwards along the straw of the sheaves, which would thus act like thatch throughout the whole stack.

There are instances of great durability of seeds, which have been preserved dry, and secured from either so great heat or so great cold, as might destroy their life or organism. Thus there is an account of the seeds of Indian wheat, which grew well in a hot-house after having been kept thirty-four years, as was accurately ascertained. Bath Society, Vol. V. p. 464. And it has been lately asserted, that many seeds of more than a hundred years old, which were found in some old herbarium at Vienna, have been made to germinate by the use of oxygenated muriatic acid and water. *Philos. Magaz.* But if the organic life of a seed be destroyed by frost, or fire, or mechanic injury, putrefaction succeeds, and decomposition ; as when the organic life of an egg is destroyed by violently agitating it, it is known soon to putrefy.

To preserve seeds in barns or granaries our principal attention should be first to make them dry, and secondly to keep them dry ; because no seeds can vegetate without moisture. The art of drying most seeds must consist in duly ventilating them, especially on dry days ; which may be done by frequently turning over the heaps of them ; and to preserve them dry in this climate the door and windows of granaries should open to the south to receive the warmth of the sun, with apertures round the building for sufficient ventilation ; which must be prevented from admitting rain or snow by sheltering boards on the outside.

The heaps of corn should be surrounded with boards to keep them from contact with brick or stone walls ; which, when warm moist

south-west winds succeed cold north-east winds, are liable to precipitate the moisture from the atmosphere by their coldness, and to communicate it to all bodies in contact with them. For a similar purpose in stables some have put up a tall wooden trunk from the chamber to the room below, three or four feet square, and ten or twelve feet high, with a sliding valve to draw out the corn below, which is poured in at the top; in three or four places a tin or wooden pipe full of holes is made to pass horizontally through the box to give air to the corn, the whole of which, when any of it is drawn out below, is moved in descending; and new surfaces of corn are applied to the air-holes of the horizontal tubes.

The most secure way of preserving a great quantity of wheat, according to Mr. Tull, is by gently drying it on a hair-cloth in a malt-kiln, with no other fuel but clean straw, and no greater heat than that of the sunshine. In this situation the wheat remained from four hours to twelve hours, according to the previous dampness of it. Mr. Tull knew a farmer in Oxfordshire who purchased wheat, when it was cheap, and kept it by thus drying it for many years, and made a large fortune by selling it again in dearer seasons. The life of the seed was not destroyed by this process; as he asserts, that some of it grew, which had been kept in this manner seven years; whereas in drying potatoes on a malt-kiln so great heat was employed as to destroy their life, and violent putrefaction ensued, as mentioned in Sect. X. 9. 2.

2. A due ventilation also, where corn is kept in the common warmth of the atmosphere in this climate, is necessary, except in seasons of frost, and also the admission of light; as otherwise the vegetable mucor, called mould, is liable to grow upon the corn, and injure it; as this mucor like some other funguses will grow, where there is little or no change of air, and without light, as in cellars, if there be sufficient moisture and warmth.

3. Another method of preserving feeds may consist in secluding them

them from heat, as in granaries beneath the soil ; which are so deep or so well covered with earth, as not to be affected by the difference of seasons. Thus there have been instances of mustard-seed producing a crop on digging up earth, which had not been removed for many years, and, as was believed, even for ages. And in ice-houses it is probable, that not only seeds might be long preserved, but perhaps fruits also ; if they were afterwards very gradually thawed by putting them into cold water, that they might not be destroyed by the too great stimulus of sudden heat, as mentioned in Sect. XV. 4. 1.

4. Where it has been necessary suddenly to collect and to preserve great heaps of corn without shelter for the provision of armies, some have moderately moistened the upper surface of the heap daily, which has occasioned the upper grains to grow, and thus to produce a sward or turf over those below ; which, it is said, has thus preserved the lower part of the magazine. But in respect to granaries for the purpose of laying up very large quantities of grain to prevent famines in scarce years, I suppose the stacks of covetous farmers, who keep their corn in cheap years, hoping to sell it at a better price in scarce ones, is a more certain method, and a cheaper one to the public, to keep up a sufficient stock of corn, than by any other experiment that can be devised.

5. Gardeners in general prefer new seeds to old for their principal crops, as they are believed to come up sooner, and with greater certainty, and to grow more luxuriantly. “ But peas and beans of a year old,” Mr. Marshall observes, “ are by some preferred to new, as not so likely to run to straw. And cucumbers and melons are best to be several years old, in order to their shooting less vigorously, and thence becoming more fruitful. But this principle is carried too far by some gardeners, who say these seeds cannot be too old, and will allow ten years to be within bounds ; three for cucumbers, and four for melons, however is age enough.

“ As to the age of seeds, at which they may be sown, it is uncertain,

tain, and depends much upon how they are kept; those of cucumbers and melons are good a long time, because very carefully preserved.

“Peas and beans will germinate very well at seven years of age; but the seeds of lettuces and kidney-beans, and some others, are not to be depended upon after a year or two; and generally speaking the smaller seeds are of the least duration.” Marshall on Gardening.

6. Where seeds of a perishable nature are to be carried to, or brought from, distant countries, I suspect that covering them in sugar would be the most certain and salutary method of preserving them; and even, that flesh meat cut into thin slices, and covered with sugar, or syrup, or treacle, would be better preserved than in brine, and afford a much more salutary nourishment to our sailors.

Since I wrote the above I have seen a paper in the Transactions of the Society of Arts, Vol. XVI. from Mr. Sneyde of Belmont in Staffordshire, who having observed some seeds, which came accidentally amongst raisins, to grow readily, directed many seeds to be sent from the West Indies covered with raisins, and others in sugar, and others in the usual manner of sending them, and found, that those immersed in sugar or covered with raisins both looked well, and grew readily; whereas many of the others would not vegetate.

Since the powder of fresh burnt charcoal is known so powerfully to absorb all putrid vapours, it is probable the seeds mixed with and covered with charcoal dust, which has been recently burnt, or not long exposed to the air, might be successfully employed for the preservation of seeds either in long voyages, or in domestic granaries.

VIII. 1. *To sow seeds advantageously* it is probable, that those of our native plants might be suffered to drop on the surface of the earth in the autumn, as they fall from their parent plants, covered only by their deciduous leaves; in which situation their fruit might contribute to nourish them, as our crabs and floes; or defend them from insects, as the acrid husk of the walnut; or from birds, as the hard stones

stones or shells of nuts and cherries, since this is the process of nature.

But when the seeds brought originally from other climates are to be sown, an attention is required to the circumstance of season and of soil. Those, which will ripen their seeds in the same year, are to be sowed in the early spring, and covered lightly with earth to preserve them from birds and insects; and should be buried thus beneath the soil, soon after it has been ploughed or dug, as its interstices are then replete with atmospheric air; which may be necessary to stimulate into elevation the plume of the embryo plant; as the moisture of the earth is necessary to stimulate the root into its elongation downwards.

Those seeds nevertheless, which will not perfect their vegetation in the same year, must be sown in the early autumn; and though all seeds vegetate better, when placed but a little beneath the surface of the soil, as one inch, because they have then a better supply of atmospheric air, which may be necessary for their first growth, before they have acquired leaves above ground; yet as many foreign seeds may not be sufficiently hardy to bear our inclement winters, it may be necessary, as some believe, to bury them an inch and a half, or two inches, deep in the soil, to prevent the frosts from doing them injury, as well as to preserve them from the depredation of birds. And the drill sowing, or sowing all kinds of seeds in rows, is the most convenient method for sowing them at a determined depth, and also for the purpose of keeping the young plants clear from weeds by the more easy application of the hoe.

To sow many seeds earlier than is usually practised is much recommended. There is a paper by Lord Orford in Mr. Young's *Annals of Agriculture*, Vol. IX. p. 385, who seems to have found considerable advantage by sowing barley so early as the seventh of February, three and a half bushels on an acre. But as much moisture with or without subsequent frost is more liable to destroy the embryo

bryon in its very early state in the seed, than after it has shot out roots and a summit, and thus acquired some habits of life; this early sowing must sometimes be practised with caution. Seeds may nevertheless be sown still earlier in hot-houses, or in warm situations, as peas, beans, wheat, and may be afterwards transplanted in the vernal months with safety and advantage. See Sect. X. 3. 6.

The difficulty of determining the best season for sowing seeds in the spring, owing to the variation of the weather in the same latitude, as well as in laying down the exact seasons for sowing in different latitudes, occasioned Linneus to construct, what he terms a calendar of Flora; which was afterwards adapted to this climate by Stillingfleet; which consisted in observing the first appearance of the rootscions, or flowers of the uncultivated native vegetables; with directions to sow the cerealia, or harvest seeds, when such plants or flowers became visible. By attention to such observations on the uncultivated native plants in many climates, it is probable, that ingenious tables might be produced, which might direct the best time of sowing the useful seeds in all latitudes, and in all situations.

Another table of the climates, where plants grow naturally, and of their native situations in respect to moisture or dryness, hill or valley, with the kind of soil where they were originally found, might also contribute to their successful cultivation.

2. In the gardens near large towns, where the land is more valuable and better manured, gardeners sometimes sow two or three kinds of seeds on the same ground for the purpose of economy. Thus Mr. Marshall observes, that “on the same ground they sow radishes, lettuces, and carrots; the radishes are drawn young for the table, the lettuces to plant out, and a sufficient crop of carrots is left; for carrots, if you wish them to be large, should not grow very near to each other.”

In defence of this mode of culture it is said, if one crop fails, the others may do well, and there is no loss of ground or time; and if
all

all succeed, they do very well. Radishes and spinach are commonly sown together by the common gardeners, and many manœuvres of inter-cropping are made by them, as the sowing or planting between rows of vegetables that are wide asunder, or presently to come off, or in the alleys of things cultivated on beds.

“ Thus if a piece of horse-radish be new planted, it may be top-cropped with radishes or spinach, &c. ; or if a piece of potatoes be planted wide, a bean may be put in between each set in every or every other row ; a thin crop of onions upon new asparagus beds, is a common practice, drawing them young from about the plants.”
Introduct. to Gardening. Rivington.

The farmer likewise, in the cultivation of grasses for feeding sheep, finds an advantage in sowing a mixture of seeds on the same ground, as rye-grass, trefoil, and clover, which are said to succeed each other in respect to the production or maturity of their herbage, as in Sect. XVIII. 1. 1. And for the purpose of preventing smut it may be useful, as I have before observed, to sow in the same ground in separate rows two kinds of wheat, one of a forwarder nature than the other ; whence if the farina of one kind should be injured by wet weather, that of the other may impregnate the ears of both. The two kinds of wheat recommended are bearded wheat and smooth-headed wheat, which are called by farmers cone wheat and Lammas wheat ; of both of which there are many varieties, and it is asserted that one third of cone wheat is frequently sowed with two thirds of Lammas wheat, and that the crops are much superior to either of them separately. Hall's Encyclop. Art. Agriculture.

In respect to kinds of soil those should be chosen, which have been found by observation to suit particular seeds, both in regard to their nutritive properties, and the moisture and warmth of their situations. And for those seeds, which produce tuberous roots within the earth previous to their flowering, as potatoes, parsnips, radishes, a soil of less cohesion should be found or prepared.

3. Add to this, that there are some seeds, as those of carrots, that are so difficult to be disseminated in uniform quantities, that it has been customary to mix them previously with sand or garden mould, for the purpose of giving them weight, or bulk, or to detach them from each other. And some even suffer them to begin to put forth their roots in such a mixture of moist sand or garden mould for the purpose of more regularly dispersing them.

In dry seasons the soaking seeds in water, a day or two before committing them to the ground, will forward their growth, as well as by artificially watering the ground before or after sowing them; and the soaking them in a solution of salt and water may have another advantage of giving an opportunity of rejecting the light seeds, which float, and perhaps of destroying some insects which may adhere to them; the sprinkling some kinds of seed with lime may also be of advantage for the purpose of destroying insects, if such adhere to them, and of attracting moisture from the air, or lower parts of the earth, or for its other useful properties; but where the seed, soil, and season, are adapted to each other, none of these condiments are required.

It may nevertheless on other accounts be very advantageous to steep many kinds of grain in the black liquor, which oozes from manure heaps. Mr. Chappel, in the papers of the Bath Society, found great benefit by steeping barley in the fluid above mentioned for twenty-four hours, and skimming off the light grains. On taking it out of the water he mixed wood-ashes sifted with the grain to make it spread regularly, and obtained a much finer crop, than from the same corn sown without preparation. To this we may add, that to steep the seed in a solution of dung in water, as in the draining from a dung-hill, is believed in China both to forward the growth of the plant, and to defend it from variety of insects, according to the information given to sir G. Staunton.

There is an old proverb, "sow dry and set wet;" but where the

earth has been lately turned over by the plough or spade, there can be no bad consequence from sowing during rain in general; but in some clay grounds much softened by rain, if seed be put into holes, and a dry season succeeds, an impenetrable crust may supervene by the exhalation of the water, and the setting, as it is called, of the clay; but even this could not frequently occur, when seeds are sown in the moist weather of the autumnal months; but generally in both cases the growth of the seed would be forwarded by the moisture.

4. Where the fruit, which surrounds any kind of seeds, can be sowed along with them, it may answer some useful purpose. Thus the fruit of crabs, quinces, and some hard pears, will lie all the winter uninjured covered only with their autumnal leaves, and will contribute much to nourish their germinating seeds in the spring. So the holly-berry and the ivy-berry remain during the winter months uninjured by the rains or frosts, and undevoured by birds or insects, and contribute to nourish their germinating seeds, when they fall on the ground in the spring. The acrid hulk of walnuts sowed along with them preserves the sweet kernel from the attack of insects; the same must be the use of the acrid oil of the cashew-nut. The hawthorn possesses both a nutritive covering and a hard shell for the above purposes; and the seeds of roses are armed with stiff pointed bristles, as well as furnished with a nutritious fruit, so long known as an agreeable conserve in the shops of medicine, *conserva cynosbati*; the former constitutes a defence against insects, and the latter supplies a reservoir of nutriment for the germinating seeds.

5. To this should be added, that in our short and cold summers the viviparous buds of some vegetables are too luxuriant, and do not produce oviparous buds soon enough to ripen their seeds, as melons and cucumbers, and many other plants, in those seasons which are moister than common. It is believed, that by washing the seeds of melons and cucumbers from the saccharine and mucilaginous matter of their fruit, and by keeping the seed three or four years before it is used,

that the viviparous buds become less vigorous, and the oviparous ones more numerous, and forwarder in their flowering; and for the production of earlier as well as of larger crops all such luxuriant vegetables should be sown early in the vernal season, or in the autumnal months, if they are not too tender to bear the winter frosts.

IX. *Question concerning general enclosure.*

The political advantage or disadvantage of the general enclosure of a country belongs to this place, as it more particularly affects the production of the cerealia, or corn-agriculture.

There can certainly be no objection to the enclosure of commons, or at least to the division of them into private property, as they are believed to produce more than tenfold the quantity of sustenance to mankind, if they are employed in agriculture, or even in pasturage, than by nourishing a few geese, sheep, or deer, in their uncultivated state covered with fern, heath, or gorse.

2. The advantage of enclosing pasture-lands, or meadows, can not be doubted; as the management of fattening cattle, of milch-cows, sheep, and horses, becomes so much easier; as well as the more convenient use of the aftermath, when the hay is carried away.

3. The lands also appropriated to the production of garden vegetables and fruit, as well as to the production of other perennial plants, which are used in the arts, as hemp, flax, madder, woad, rhubarb; and of the esculent roots or herbage raised for the consumption of cattle, as turnips, potatoes, carrots, cabbages, certainly require to be enclosed.

4. The political question therefore finally concerns only the arable lands; and asks simply, whether a general enclosure of arable lands be favourable or unfavourable to the population, and consequent prosperity of the country, which must depend on the comparative quantity of nutritive provision, which is likely to be produced from the different modes of its cultivation.

Now as pasturage requires fewer hands in the management of it, and less art and attention to conduct it, than agriculture; and as its products in flesh, cheese, butter, take a higher comparative price at market, and are articles of greater luxury, than the products of arable land in corn, we may conclude, that pasturage will prevail in all enclosed provinces over agriculture. And as perhaps tenfold the numbers of mankind can be supported by the corn produced on an hundred acres of land, than on the animal food which can be raised from it, it follows, that an enclosed province will afford sustenance to a much smaller population; and as the number of inhabitants of a country depends on the ease, with which parents can procure sustenance for their families, marriages will become fewer, and the people decrease, when an arable country is converted into pasturage.

This last circumstance appears already to operate in these realms, since about half a century ago much corn was exported annually, but for several years last past great quantities of it have been annually imported for our own sustenance; and that even though potatoes are much cultivated, and must therefore lessen the consumption of grain, and the ungraceful fashion of covering the head with wheat-flour is much diminished. Is this to be solely ascribed to the numerous enclosures of arable lands, or in part to the consumption of corn in the distilleries?

One very important consequence of any country producing a greater quantity of corn, than it consumes, and of thence exporting it to foreign nations, even by means of a bounty, consists in its certainty of preventing famine, the most dreadful of human calamities; as in years of scarcity the stream of exportation can be stopped, and produce an ample supply by its stagnation at home.

Hence when a great part of any tract of country becomes employed in pasturage instead of agriculture, the inhabitants will become consumers of flesh instead of consumers of grain, and will consequently decrease in number from the want of sufficient sustenance.

Besides which the people of agriculture are more active and robust than the people of pasturage, and more ingenious in the invention and use of machines necessary for the more artful cultivation of the soil, as well as more numerous, and will consequently become superior to them in arms and arts, and may in process of time conquer them; which reminds us of the Egyptian Dynaſty of Shepherd-kings, who were subdued by their agricultural rivals; and also of the allegorical history of Cain ſlaying Abel, which were probably the names of two political hieroglyphic figures representing the ages of pasturage and of agriculture before the invention of letters.

It muſt hence certainly be an object of good policy to encourage agriculture in preference to pasturage, which in this country might be effected by preventing the enclosure of arable lands, and also of thoſe parts of commons, which are beſt adapted to the growth of corn; though the whole might be advantageouſly divided into private property. Unleſs ſome other means could be deviſed of preventing a nation from becoming too carnivorous, or of duly promoting the cultivation of grain, the former of which was heretofore produced by religious faſt-days twice a week, and the latter by bounties on the exportation of corn. To which might be added a total prohibition of the deſtructive manufactory of grain into ſpirits, or into ſtrong ale, and thus converting the natural nutriment of mankind into a chemical poiſon, and thus thinning the ranks of ſociety both by leſſening their quantity of food, and ſhortening their lives by diſeaſe.

In many villages, where much arable lands have been lately enclosed, the numbers of labouring people have quickly been much diminished both by the ſcarcity of food, and want of employment.

Worſe fares the land, to haſtning ills a prey,
Where wealth accumulates, but men decay;
Princes or lords may flouriſh, or may fade,
- A breath can make them, as a breath has made;

But

But a bold peasantry, their country's sword,
When once destroy'd, can never be restor'd.

GOLDSMITH'S DESERTED VILLAGE.

Mankind nevertheless seems by nature to be designed to subsist on both vegetable and animal nutriment, which appears from the length of his intestines, which like those of swine are much longer than the intestines of carnivorous animals, and much shorter than those of the vegetable eaters; and which also appears from the structure of his teeth, which partakes of the structure of those of the carnivorous and phytivorous animals; and lastly, because those people, who live solely on vegetables, as the Gentoo tribes, and those who subsist solely on animals, as the fish-eaters of the northern latitudes, are undoubtedly a feebler generation than those of this country, who exist on a mixture of both. A due proportion therefore of the two kinds of nourishment, such as perhaps at present exists, or lately did exist, in this nation, must be decidedly the best; the preservation of which, with the prohibition of spirits, or of strong fermented liquors, except occasionally as medicines, might probably render these kingdoms more populous, robust, prosperous, and happy, than any other nation in the world. But if the luxurious intemperance of consuming flesh-meat principally, and of drinking intoxicating liquors, should increase amongst us, so as to thin the inferior orders of society by scarcity of food, and the higher ones by disease both of mind and body, it may hereafter be said of Great Britain, amid her foreign conquests, as formerly of ancient Rome,

Sævior armis
Luxuria incubuit, victumque ulciscitur orbem.

S E C T. XVII.

PRODUCTION OF ROOTS AND BARKS.

Barks of trees are similar to their roots. All roots now known were originally from seeds. I. 1. Tuberous or bulbous roots of turnip, carrot, parsnip, beet, are reservoirs of nutriment for the future stem. Not so in grasses. Sugar visible in beet roots. Small beer from parsnip roots. Alcohol from carrots. The knobby root and flower-stem are successive plants. Select forward seeds from vigorous plants, and a soil not cohesive. Radishes on hot-beds. 2. Tuberous roots from subterraneous wires, as potatoes. Pinch off the flowers. Make a cellular soil. Aerial potatoes. Curled leaf of potatoes. Sow the seed. Plant large roots and whole ones. Early potatoes. 3. Improve ground artichoke and pignut by seed. 4. Onions, method to improve them. 5. Orchis, ripen the seeds of it. Snow drops. Hyacinths. Crocus. Martagon lily. II. 1. Palmated, or branching roots, not immediately from seed. Perennial roots, like barks of trees, continue to increase in size. Should remain four or five years in the ground, not longer, as rhubarb. 2. Pinch off the flowers, as in rhubarb. 3. Roots of aquatic plants. *Nymphaea*, butomus, cultivated for nutriment, wine, or vinegar. 4. Art to preserve roots. Keep them alive, between 32 and 48 degrees of heat, covered with pounded charcoal, saw-dust, and thatch, or dry them by ventilation and heat. 5. Of musbrooms. Their gills are their lungs. Are animate beings without locomotion. Are of animal origin. Conduct galvanism. Musbroom stone, truffles, morels, musbrooms with acrid juice. Ear-fungus. III. 1. Barks contain sugar and mucilage, and other ingredients. They should be taken off before the buds expand. 2. Oaks, why barked in spring. 3. Barks of elm and maple might make small beer. Of holly esculent. Bird-lime like caoutchouc. 4. Bitter, aromatic. Acrid barks. 5. Restraining and colouring barks for tanning and dying. 6. Fibrous barks of flax, papyrus, mulberry, and birch. 7. To increase the bark pinch off the flowers.

flowers. 8. Rub off the moss. Sprinkle with water. 9. Wounds of the bark. Paint the naked alburnum. 10. Canker. Bind on a new bark. Plant the branch in a divided garden-pot.

As the barks of trees are composed of a congeries of the long caudexes of the individual buds, which consist of the absorbent vessels, which imbibe nutriment from the earth, and of the arteries and veins, which supply nutriment to the growing vegetable; of the glands, which secrete from the vegetable blood the various acrid, astringent, or narcotic, juices to defend them from the depredation of insects; and the various mucilaginous, oily, or saccharine, materials for the nourishment of their embryon buds; and lastly, of the organs of reproduction. There exists the strongest analogy between the barks of the trunks of trees, and of their roots, in every respect; except that the former possesses a cuticle adapted to the contact of the dry atmosphere, and the latter a cuticle adapted to the contact of the moist earth, which differ from each other like the external skin, and the mucous membranes of animals. And finally, as these long caudexes of the buds of trees, which form the filaments of the bark, terminate in radicles beneath the soil, and in leaves in the air, like the broad caudexes with the radicles and ascending stems, or foliage, of herbaceous plants, they exactly resemble each other.

We shall therefore divide roots for the purpose of treating of their production into bulbous or tuberous roots, into palmated or branching roots, and into barks; observing that though roots and buds might possibly have existed before seeds, and though a great number of the roots used for nutriment, or for the purposes of medicine, or for the arts of dying and tanning, are immediately produced by buds, or bulbs; yet are they all, which we now possess, originally derived, I suppose, from seeds; because those varieties, which have been propagated from buds or bulbs for many centuries, are believed to acquire hereditary diseases, and gradually to perish.

1. *Of tuberous and bulbous roots.*

1. Some tuberous roots, as the turnip, *brassica rapa*, are immediately produced from seeds, but differ from the other plants, which are called annual or biennial, in this circumstance; that, as they are generally sowed so late in the season as not to have time to produce flowers and seeds in the same year, they produce a knobby root, which consists of a reservoir of nutritious matter for the future flower-stem, which is to rise and flourish in the succeeding spring and summer; whereas the common annual grasses, as oats and barley, do not previously lay up a magazine of nutriment in their roots, but in their joints, which are sweet; and therefore their roots are not used for culinary purposes, or for provender.

Other tuberous roots are raised in the same manner from seeds, but are generally sown also so late in the season as not to form their flower-stems in the same year; as the carrot, *daucus carota*; the parsnip, *pastinaca sativa*; and the beet, *beta vulgaris*; these also lay up a store of mucilaginous and saccharine matter in their roots for the growth of the future flowers. In the beet-root the crystals of sugar are sometimes visible by a microscope; and I was well informed, that a labourer in Lincolnshire made small beer from a decoction of parsnip roots, which was spirituous enough, and not of disagreeable flavour; and Mr. Hornby of York, by boiling carrots, and fermenting the juice expressed from them, produced two hundred gallons of proof spirits from twenty tons of carrots. *Edinb. Transact. Vol. II. p. 28.* Now as all vinous spirit has been sugar, there is foundation to hope that a method may be discovered of producing and separating sugar from these plants of our own climate in sufficient quantity for our domestic consumption, or even for exportation.

Other tuberous roots are propagated from seeds in the same manner; and though they are sowed early, and produce their flower-stem and seeds in the same year, yet they form a knobby root, which consists

sists of a magazine of nutritious matter, previous to the elevation of the flower-stem, as the radish, raphanus sativus, and carrot, and beet, when sown early. I nevertheless suspect that these, as well as the preceding, consist in reality of two successive plants; that which forms the knobby root, and that which is formed from it, as spoken of in Sect. IX. 3. 6.

For the production of roots of these kinds, which are immediately or secondarily propagated from seeds, our attention must be applied to collect the forwardest seeds, and from the best plants of the kind; and to sow them at the proper season of the early spring, or early autumn; and in a soil which contains sufficient vegetable nourishment, observing, nevertheless, that as carrots, parsnips, beets, and radishes consist of knobs formed in the ground, a less adhesive soil is to be selected; as one abounding with siliceous or calcareous sand, as well as with carbonic earth. But as the turnips are formed chiefly above ground, this attention to the cohesion of the soil becomes less necessary, so that it is sufficiently penetrable by the fibres of their radicles.

There is another art of producing larger roots from seed, and at an earlier season, as of radishes; which is by sowing them in hot-beds in the early spring, and exposing the tops to the cold air during the day, as this prevents the luxuriant growth of the summit, and increases that of the root.

2. Other tuberous roots are generally propagated by subterraneous wires, or root-buds, from the tuberous roots of their parents through a long generation, and not either primarily or secondarily from seeds; as the potato, *solanum tuberosum*; and the ground artichoke, or tuberous sun-flower, *helianthus tuberosus*; and perhaps the pignut, *bunium bulbocastanum*.

As the tuberous roots of the potato planted in the spring not only produces many other similar tuberous roots, but flowers also during the summer; I was led to suspect, that pinching off the flowers, as

they appeared, would contribute to increase the number or enlarge the size of the new roots; which experiment has been made on a small scale by one, who believed it to succeed in a degree decisive of its utility. See Sect. XIX. 3. 1. and Sect. VII. 1. 3, where it is said, that pinching off the flower-stems of bulbous-rooted flowers, when they first appear on young bulbs only a few years from the seed, is believed to render the flower duplicate.

As the roots of potatoes are formed beneath the earth, the soil, in which they are planted, should be laid hollow and full of cells, or should possess less cohesion than usual, to facilitate the protrusion of their wires, and the enlargement of their roots. This should be done by burying some long litter of straw and stable dung under the soil; for as potatoes are believed to require more carbonaceous earth than carrots, a mixture of sand is less advantageous to them.

I was this day shewn by my friend Major Trowel of Derby a new variety of the potato in his excellent new-made garden, the soil of which consists of marl mixed with lime and stable-manure. From one root there appeared to issue six or eight stems three or four feet long, at every joint of which were produced new potatoes; at the lower joints there were three of these aerial potatoes, one large one the size of a pullet's egg, and a smaller one on each side of it. At the upper joints only one new aerial potato adhered, and these became smaller the further they were removed from the root; and finally, at the summit there had been a flower as there was now a seed-vessel, called a potato-apple. All these new potatoes at the joints of the stems were green, because they had not been etiolated by being secluded from the light, but the terrestrial roots were white. The larger new tuberous roots had eyes on them like a common potato, but the smaller ones had begun to shoot out a new stem or leaves from their upper part. This variety, which may be termed an aerial potato, is analogous to the magical onion, and other species of *allium*, which bear cloves, or roots on their summits instead of seeds,

and like the viviparous polygonum ; but differs in this circumstance, that in all those, I believe, the flowers are barren in respect to bearing seeds, as those are on the summit of the spike of polygonum viviparum ; but in the aerial potato there was also a seed-bearing flower at the summit of the stem, and the new roots only at the lateral joints. I should hope this proliferous variety by cultivation may become permanent, and give rise to a new species, which may produce both aerial potatoes and subterraneous ones, a twofold viviparous progeny.

The curling of the leaves of potatoes, which is attended with so great a diminution of the quantity and size of the new roots, is supposed to be owing to their continued propagation by subterraneous buds or root-wires, instead of by seed ; that hence they acquire hereditary diseases, like the canker or gangrene of apple trees, which have for one or two centuries been propagated by grafting the scions, as mentioned in Sect. IX. 3. 4. and XV. 1. 4. Hence by sowing the seeds of potatoes, and cultivating the roots thus produced, new varieties may probably be soon acquired, exempt from the disease of the curled leaf, and which may be as good in other respects as those which have been too long propagated by their roots. Some have nevertheless affirmed, that they have seen curled potato-plants in the second year from the seed ; and others, that they have seen numerous insects on these curled leaves ; and others, that the potato-root, the leaves of which are curled, remains hard, and less dissoluble in the soil, which I have myself witnessed. More observations are wanted to elucidate this subject.

Another cause of the degeneracy of potatoes has arisen, I believe, from planting the least instead of the largest roots, see Sect. XVI. 5. and which consequently possess less vigorous vegetation, as buds and bulbs so exactly resemble the parent plant. Thus the small bulbs, which arise from tulip-roots, will produce a rather larger bulb annually for three or four years, as I am informed ; but it is the large

new central bulb only, which will produce a flower the next summer, and another large central bulb like itself. See Sect. IX. 3. 1. Another cause of the degeneracy of potatoes may arise from dividing the larger roots into too many sets, which must deprive the embryo plant of much of its appropriated nutriment; as the umbilical part of the root is generally thrown aside by those idly-ingenious dissecters of it; for though the part, where the umbilical vessels were inserted, may not after the mature growth of the bulb appear to possess new vessels from the embryo plants, such as are seen on the lobes of a growing garden-bean; yet, as it becomes decomposed, it must supply mucilaginous or saccharine nutriment to the roots of the new plants.

As the potatoes raised from seeds do not flower on the second or third year, resembling in this circumstance the bulbs of tulips and hyacinths; these new roots, I am told, are sold as early potatoes, and that they are forwarder in their growth from their being generally planted without being divided; and that they form their new roots sooner, as they do not flower. To improve the seeds of potatoes see Sect. XVI. 3. 4.

The following method of planting whole potatoes is recommended in Mr. Adam's Essays on Agriculture, and has a promising appearance.

"The idea," says he, "which I mentioned before, respecting the culture of the Scotch and Anjou cabbages, might be successfully applied to that of potatoes. Let us suppose the ground, in which they are to be set, is properly prepared by plowing: let then the furrows be drawn in it at four feet distance all over the field, and crossed by other furrows at an equal distance. Where these intersect each other lay in some dung from a wheelbarrow, extending from the point of intersection fourteen or fifteen inches each way: let a man following spread a little of the mould from the furrow over the dung; let a third hand put one whole sound potato at the point of intersection,

tion, and one in each furrow, at a foot distance from the centre, which will make five in all: a fourth hand should now follow with a barrow full of leaves, and lay them over the plants; should then sprinkle some mould lightly over them, and leave them so till the plants shoot.

“ Thus the plants will occupy a space of two feet each way, out of the four feet between the furrows; and the remaining intervals between the plants on each side will also be two feet, which intervals I would horse-hoe at the proper periods, first one way of the field, and then across, laying the mould upon the plants at each hoeing, so that the spaces which the plants occupied would by these means become little square hills filled with roots; and the intervals between being thus hoed and cross hoed, would have the usual good effects of pulverizing the soil, destroying the weeds, and preparing the land in the best manner possible for a crop of wheat.”

3. The ground artichoke, *helianthus tuberosus*, seldom ripens its seeds in this country, and might probably be much improved by using methods to ripen the seed, which are mentioned in Sect. XVI. 3. 4; and by thus producing new varieties; and the pignut, *bunium bulbocastanum*, might probably by cultivation from the seed supply an agreeable and salutary root to be eaten like chestnuts either raw or roasted.

4. The seeds of the common onion, *allium cepa*, generally produce no flower-stems the first year; but each seed produces concentric leaves, which gradually form a large bulb below them with one or two, and sometimes three, less internal bulbs, included within three or four general concentric coats, besides the three or four coats appropriated to the individual bulbs, as described in Sect. IX. 3. 2. On the next year some species of this genus produce bulbs after their flowers instead of seeds, as *allium sativum* and *magicum*; others produce not only flowers but also bulbs, as *allium moly*, and *spherocephalum*. If the bulbs of these least kinds of *allium* were planted with

with design to produce other bulbs, and not to produce seeds ; it is probable, that pinching off the flowers might enlarge the new bulbs, as the pinching off the flowers of potatoes ; and that by such means a larger kind of bulbs of some of this genus might be procured.

5. Another bulbous root, which might be well worthy cultivation in moist ground, is the orchis morio ; which is sold under the name of salep, after it has been prepared by first scalding it in hot water to detract the skin, and afterwards by drying it in an oven ; and which then affords a nourishing mucilage, which will long keep uninjured. And, if it was cheaper, might probably be brought into more extensive use as a culinary vegetable, as mentioned in Sect. XVI. 3. 4. The orchis morio produces one large new root annually, and probably some smaller offsets, as otherwise I do not perceive, how it could increase in our meadows, as it does not ripen its seeds in this country.

If the new root be taken away from the old one early in the year, it is affirmed, that the seeds will ripen in Sweden ; which are otherwise in that country, as in this, always unprolific ; this experiment might therefore be very advantageous to the cultivator. Another method of inducing orchis to bear prolific seeds may be by confining the roots in garden pots, which might be immersed in a moist soil, and would probably bear ripe seeds ; as the lily of the valley, convallaria, is said to do by crowding its roots so much as to prevent the production of more of them, *Amenet. Academ. Vol. VI. p. 120.* A third method of procuring seed from orchis might be by cultivating a few of them in a hot-house for that purpose.

The root of the snow-drop, galanthus, if dug up in winter, and prepared in the same manner, might possibly supply a nutritious mucilage similar to that of the orchis ; as I once boiled a few of them, and found on tasting them, that they had no disagreeable flavour. If prolific seeds could be procured from this plant, it might be worth cultivation for the same purposes as the orchis ; and the roots of the hyacinth,

hyacinth, I am informed, are equally insipid, and might be used as an article of food; but the roots of crocus, which I boiled and tasted, had a disagreeable flavour, and might probably therefore be insalubrious.

Mr. Gmelin in his History of Siberia asserts, that the roots of the *lilium martagon* are used as food in that country; and it is probable, that the root of the *arum*, though it be acrid in its raw state, might supply palatable and salutary nutriment by cookery; as Mr. White asserts in his History of Selborne, p. 43, that it is scratched up and eaten by thrushes in severe snowy seasons, and it is known soon to lose its acrimony even by exposing its dry powder to the air; we may add, that the root of the *asphodelus ramosus* is used to feed swine in France, and that good starch is obtained from the roots of white bryony and of *alstromeria licta*.

Other bulbous roots are propagated by florists with great attention for the beauty of their flowers, as tulips, hyacinths, lilies, and many others. For an account of some of these see Sect. IX. 3. on the growth of bulbs, and Sect. XIX. 3. 1. on the production of flowers.

II. *Palmated or branching roots.*

1. The bulbous and tuberous roots already mentioned were either such, as were primarily derived from seeds, as the turnip, carrot, parsnip, radish, beet, farsaf; or such as were secondarily derived from seeds, but immediately from bulbs or knobs similar to themselves, as potatoes, ground artichoke, orchis, pig-nut. But the branching or palmated roots, which are used as food, or in medicine, or in the arts of dying, are seldom produced immediately from seeds, but generally from preceding roots, and are hence the product not of annual but of perennial plants; as the root of liquorice, *glycyrrhiza*; of marsh mallow, *alcea*; of rhubarb, *rheum*; and of madder, *rubia tinctoria*.

The roots of these perennial plants shoot out not only annual
stems.

stems with numerous flower-buds above ground, but also other new buds on their caudex, or upper part of the roots beneath the soil; all which buds protrude their new caudexes not only over those stems, but also over the old root-branches; and thus form annually a new bark over the old root, which remains alive beneath the ground, though the stem perishes by the winter frosts. This happens exactly in the same manner as the bark of trees, which annually is produced over the old bark of the root as well as of the trunk; but in trees the stem-bark as well as the root-bark survives the winter.

Hence these palmated or branching roots of perennial herbaceous plants, as of rhubarb, madder, liquorice, continue to increase in size by the super-addition of an annual new bark; but in four or five years the internal part begins to decay, and the roots therefore should be taken out of the ground for use before that time. It is said in the transactions of the Society for Encouragement of Arts, Vol. XVI. p. 226, that those rhubarb roots, which were not taken up, till they were seven or more years old, were most of them good for nothing from the decay of the internal part of the root. The same is said to happen to some bulbous roots, as the hyacinth; and occurs in all those roots, which are said to be end-bitten, as a species of scabius called devil's-bit. See Sect. IX. 3. 5.

They should then be taken up in the winter months, before the new buds or flower-stems begin to acquire nourishment from the root, by which it would be deprived of a part of the nutritious, colouring, or medical matters; which principally reside in the bark, or alburnum of it. On this last account also these roots should not be permitted to continue in the ground a much longer time than that above mentioned, though the internal or woody part of the root may not decay; as the woody part is less adapted to the purposes expected than the bark and alburnum, which cover or constitute the numerous branches of the root.

2. One method to increase the size of these palmated or branching

ing roots may be by pinching off the flowers, as soon as they appear, when the seeds are not wanted; this I once saw practised on the *rheum palmatum* with apparent advantage, as well as on potatoes, as mentioned above; as more nutriment may thus be derived to the new buds forming on the roots.

The colouring matter sold under the name of annotta, or arnotta, which is said to be obtained from the skin of the kernel of the bixa of South America, or of the *enonymus* shrub cultivated in our gardens, is believed to be much adulterated with madder, *rubia tinctoria*; the root of which for the purpose of colouring cheese may be used instead of arnotta, and is to my knowledge a perfectly harmless root, though it tinges the bones of young animals red, who eat it mixed with their food, and may be grown by cheese-farmers in their own gardens, as it is a very hardy perennial plant, and requires no art of cultivation. It may be used either by pounding the fresh root and boiling it in water, or by drying the root for the purpose of preserving it, and afterwards bruising and boiling it.

For the cultivation of *rubia tinctoria* see Miller's Gardener's Dictionary, who describes with several plates the manner of growing and of afterwards preparing this root in prodigious quantities in Holland; and adds, "that if the cultivation of madder was carried on properly in England, that it would not only save to the nation the great annual sum now expended in the purchase of it from the Dutch, but would employ a great number of hands, from the time harvest is over, till the spring of the year, which is generally a dead time for labourers; and the parishes might thence be much eased of the poor's rates, which is a consideration well worthy public attention."

The external part of the root of *rubia tinctoria* is coloured red, and its internal part yellow, which distinguishes it from most other roots, which are generally etiolated owing to their seclusion from the light; which liberates their superfluous oxygen, which otherwise deprives them of colour as in bleaching, by uniting with their colouring mat-

ter, and converting it into a colourless acid, except where the colouring matter abounds in too great quantity. This etiolation of most roots is evidently owing to the want of light, because many of them, as of white potatoes, become green if they grow above ground.

3. The roots of some aquatic plants are used in medicine both of the bulbous and palmated kinds, as *scilla maritima*, squill or sea-onion, and the *iris luteus*, yellow water flag, and the *acorus calamus*, aromatic flag. Other aquatic roots are said to have supplied food, as the ancient lotus in Egypt, which has been by some writers supposed to be the *nymphaea nelumbo*. Herodotus affirms in his *Enterpe*, that the Egyptian lotus grows in the Nile, and resembles a lily; and that the natives dry it in the sun, and take the pulp out of it, which grows like the head of a poppy, and bake it for bread. The white-flowered and the yellow-flowered *nymphaea* of our ponds and rivers has a palmated root sometimes three inches in diameter. In Siberia the roots of the *butomus*, flowering rush, are eaten; both which well deserve further attention, as they grow spontaneously in our ditches and rivers, which at present produce no esculent vegetables, and might thence become an article of useful cultivation. See Sect. IX. 2. 5.

Some other aquatic roots, as well as terrestrial ones, might probably become esculent and nutritive by boiling or roasting them to destroy their acrimony. Or it is probable, that a wholesome starch might be obtained from them, as from the roots of white *bryonia*, as is affirmed by M. Parmetier, by the simple process of grating the root by a bread-grater of tinned iron into cold water, and depriving it of its acrid mucilage by frequent cold ablution. And lastly, that they might be so managed as to undergo fermentation either by previous germination, or by adding yeast to the juice expressed from them after boiling, and thus be converted into wine or beer, from which a spirit might be distilled, or vinegar produced. See Sect. XI. 2. 5.

4. The art of preserving roots, when taken out of the ground, consists

consists either in keeping them alive during the winter without suffering them to germinate, as life prevents the fermentation or putrefaction of their juices; or secondly, by depriving them of their water. For the first purpose the roots, whether bulbous or palmated, should be kept in a degree of heat above the freezing point of 32; since freezing them destroys their life; whence they not only undergo a sudden change in their flavour and nutritive quality, but quickly tend to putrefaction in consequence of their loss of life like the eggs of animals. Nevertheless both vegetable and animal products, as fruits and flesh, as well as roots, may probably long exist unchanged in a frozen state in ice-houses; and if they are at length gradually thawed by covering them with melting ice, or immersing them in cold spring water, it is said by Mr. Reaumur, who tried the experiment on apples, that they do not lose much of their flavour, if they be afterwards soon made use of; otherwise, I suppose, as the frost has deprived them of life, they soon begin to undergo chemical changes.

If these roots are kept in a degree of heat above 48, which is the heat of the internal parts of the earth, and consequently of spring water, they are liable to germinate, as happens to onions and potatoes in our store-houses during the vernal months. And if they be exposed to a much greater heat, so as to destroy the life of the root, they soon run into fermentation or putrefaction, or become covered with mould; unless the water which they contain be quickly dissipated by evaporation. A friend of mine once sent many strikes of potatoes to be dried on a malt-kiln, hoping by that means to preserve them during the summer; but as the life of these roots was destroyed by the degree of heat, and only about half of their water evaporated, they soon became so putrid after being returned into his store-room, that the stench of them was intolerable, and even the swine refused to eat them. Nevertheless I believe, if the parts either of vegetables or animals could be kept in an heat at or above the boiling point of 212 in close vessels, so as not to suffer their fluid part to eva-

porate, that neither fermentation nor putrefaction would ensue; but that they might be kept for years unchanged, as in the cold of 32.

The degree of heat required for preserving roots secure from frost, and from the process of germination, which is that between the degrees of 32 and 48 of Fahrenheit's thermometer, may be well managed by storing them beneath the soil in dry situations, as in dry cellars, or in pits dug for that purpose, or even in barns; but this requires more attention than is usually employed in the common manner of storing potatoes, which are liable to be injured both by frost and by germination. These pits in a dry soil should be covered with materials, which conduct heat ill, and also with such as might absorb any putrid exhalations, which may occur, and thus check the progress of putrefaction, if it should commence.

Air is a bad conductor of heat, if it be confined over the surface of any body, but not so if it be perpetually changed; as it then carries away heat very rapidly, as any one may experience by being fanned on a hot day. Hence all such materials as possess large pores or interstices full of air, are bad conductors of heat; as blankets, saw-dust, wood-shavings, or straw; and will thence preserve the bodies, they cover, both from external cold and from external heat. But as charcoal in coarse powder not only includes much common air in its pores, but also has the property, especially if recently burnt, of absorbing putrid exhalations; and is also itself of an unperishable nature; it seems peculiarly adapted to the purposes above mentioned. Hence the heaps of potatoes, or carrots, or parsnips, or ground artichokes, or even the roots of turnips or of beets, and the heads of cabbages, and perhaps pears, and apples, as well as nuts, almonds, and walnuts, might be well preserved in pits or cellars, or even in barns, if they were first covered with powdered charcoal an inch or two in thickness, and over that a covering of saw-dust, and finally over these a thick impenetrable thatch of straw; whence a store of provender for the winter months and the succeeding spring

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may be preserved from any degree of cold or of warmth much above or below that of the internal parts of the earth, in which seeds are known to continue for ages even without germination or decay.

It is nevertheless necessary to dry many palmated roots, when they are taken out of the ground, either because they will not continue to live in our barns or store-rooms, like the bulbous roots, or because they require to be kept for some years in the shops of medicine. Some of these roots, as those of rhubarb, are said like the bulbous roots of scilla or squill to contain five sixths of their weight of water, and therefore require considerable care in the method of drying them; for unless they are properly dried, they are liable to contract mould or mucor; which is a vegetable production, which will grow on putrefying materials without light or much air; but might be prevented from growing by the vapour of perhaps a teaspoonful of spirit of wine, as mentioned in Sect. XV. 2. 3.

There is nevertheless some precaution necessary in exhaling the moisture of these roots, as they should be placed in a situation, where they are ventilated as well as heated; for warmth alone is liable to forward the tendency of the saccharine and mucilaginous parts of them to pass into fermentation or putrefaction, and thence to destroy them; as the alburnum or sap-wood of timber trees is liable to decay by what is termed the dry rot.

With this design drying houses are constructed for the preparation of madder, *rubia tinctoria*, as described in Miller's Dictionary; and the rhubarb of the shops has frequently large holes bored through it; which, it is supposed, were designed to pass cords through for the purpose of suspending it to dry, as it is conveyed on camels in a warm climate.

5. The cultivation of mushrooms, morels, and truffles, *agaricus*, *phallus*, *lycoperdon*, should be here mentioned; as they are propagated by their roots. The fungi seem to constitute an isthmus between the two great continents of nature, the vegetable and animal kingdoms.

kingdoms. The odour of a fungus, when burning, approaches to that of burning feathers; and all of them putrefy like animal flesh; some of them as the phallus impudicus, stink-horn, emits such a putrid scent, as it grows, as to attract innumerable flesh-flies to deposit their eggs or spawn in it. And those mushrooms, which are cooked at our tables, as well as the catchup, made by preserving their juices in salt and water, possess an animal flavour. Of this last circumstance I was told a remarkable instance, where a cook-maid in a family of invalids, who frequently wanted weak broth, perpetually deceived them by a mixture of a small quantity of good catchup with thin gruel, and with only the addition of shred leaves of parsley, and a little salt.

Another thing in which the funguses differ from vegetables, consists in their growing perfectly well without light, which is so necessary to the health of vegetables. The scarlet folds beneath the head of the common esculent mushroom are so like the gills of fish, that they have in our language obtained the same name. These folds beneath the hat of the agarics, the pores beneath the boletus, and the thorny appearance beneath the hydnum, and the net-like pores of phallus, are all different means of exposing a larger surface to the air; and therefore undoubtedly constitute the lungs of the funguses, as leaves constitute those of vegetables, and not their organs of reproduction, as some have supposed.

The chemical analogy, which exists between some of the mushroom tribe and animal matters, led Van Humboldt to investigate their conducting power of what he terms the galvanic fluid, which I believe to be simply a minute shock of the electric fluid; and he found, that morels and those fungi, which in a state of putrefaction emit a cadaverous animal smell, are equally good conductors as real animal substances. Annals of Medicine for 1798, Edinb. Van Humboldt asserts further, that by chemical analysis they approach likewise to animal substances, as they contain much azote and phosphorus. He also asserts, that he converted morels into fat by means
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of sulphuric acid diluted with water, which experiment he thinks is analogous to that of Gibbes, and of the burying ground of the Innocents, where fat was formed from muscular flesh. *Journal de Physique*, Vol. IV. p. 67.

The fungi would hence appear to be animals without locomotion, whose lacteal vessels are inserted into the earth, like those of vegetables; but whose gills or lungs are covered from the light, like those of animals, but exposed to the open air like the leaves or lungs of vegetables. Another curious occurrence, which seems to associate them with animals, if the truth can be depended upon, is that some of them are of animal origin; as the common mushroom is said certainly to be procured from horse-dung, as mentioned below; and may therefore have its embryo or early state in the intestines of animals, and its maturer state in the soil or atmosphere like other insects, as the bot-fly, and perhaps the tape-worm, and ascarides? as this production of mushrooms is otherwise contrary to all known analogy. Other fungi are found on the decayed parts of peculiar vegetables, from which they seem to take their origin, perhaps like worms in the intestines of animals, as the agaric of the oak, of the beech, of the elder; the boletus of the beech, and of the willow; and many others mentioned by Linneus.

The lycoperdon tuber, or truffle, grows under ground without light, never rising into day; and is propagated, I suppose, by only a paternal or lateral progeny, like the polypus of our ditches, and not by sexual connexion, or seminal progeny. The truffle is hunted by dogs probably from its possessing somewhat of an animal scent, like the perspirable effluvia left upon the ground, by which they hunt their game or discover the foot of their master.

The phallus esculentus, morel, and the agaricus, mushroom of various kinds, will grow without light in cellars, or on beds covered with straw; and are also, I suppose, propagated by a paternal or lateral progeny only, and not by a sexual or seminal one.

The roots, or spawn, or embryos, of the common mushroom are said by Mr. Kenedy and others to be certainly procured from horse-dung laid unbroken in small heaps under cover. It is asserted, that in a few weeks during the summer months these roots will appear like white threads; which on breaking the lumps have the mushroom smell. These horse-droppings are directed to be as little broken as possible, and to be laid about three inches thick on a hot bed of moderate warmth, constructed of alternate layers of tanner's bark and horse-dung, and whose uppermost stratum consists of tanner's bark about two inches thick. The bed is then to be covered with a little manure, and about three inches of good soil, and finally with a thick coat of straw. The shed behind most hot-houses is found to afford a convenient place for a mushroom bed; as no light is required, but only warmth, and occasional moisture. See Kenedy on Gardening, Vol. II. for a particular account of this process.

In the tanyards of Derby, I am well informed, that a production of mushroom spawn always occurs in the path, where the horse walks, which draws the rolling stone to grind the bark, which path consists of powdered oak-bark and horse-dung trampled together. Of this I was in one instance an eye-witness, but whether the embryos of mushrooms were derived from the oak-bark or horse-dung was not easy to determine.

Mr. Ferber, in his Travels through Italy, translated by Raspe, mentions the mushroom-stone. He says "the *pietra fungaia* is a white calcareous stalactite, or tuff-stone, dug in the limestone hills bordering on Romagna, and endowed with the quality to produce in any season of the year esculent mushrooms, if kept in a moist cellar, and now and then sprinkled with water. This quality is owing to a great many roots, or vegetable fibres, together with the mushroom seeds enclosed in its substance. They are used in some great houses in Naples and Rome. I saw an indurated mould from the same place
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that had the same quality, which was used by Mr. Fabriani in the mint of Florence."

From this account the mushroom-stone appears to consist of a porous tupha, like that with which the houses are built at Matlock Bath; and which has been deposited from the water. But a later writer has since analysed one of these stones, but does not mention how long it had been used for the vegetation of mushrooms, which might in great measure affect the results of his analysis. Mr. Gadd, in the Stockholm Transactions, says, that this *pietra fungaia* described first by Ferber consists of forty-five or forty-six hundredth parts of siliceous earth, and twenty of a calx of iron, with a little magnesia and vegetable alkali. *Analytic. Review*, Dec. 1798.

In this country the cellars would not be sufficiently warm to produce mushrooms at any season of the year; but as this mushroom-stone is of calcareous origin according to Ferber, it shews, that calcareous earth is friendly to the growth of mushrooms; and a similar porous stone from the vicinity of Matlock Bath might probably be permeated in a similar manner with the roots of them, as a convenient repository of them to be raised into life occasionally by warmth and moisture.

Some of the fungi are believed to possess an intoxicating quality, and are eaten for that purpose by the peasants in Siberia. One fungus of the species *agaricus muscarum* eaten raw, or a decoction of three of them, produces intoxication for twelve or sixteen hours. *Hist. of Russia*, Vol. I. Nichols, 1780. The Ostiachs also blister the skin by a fungus found on birch-trees, and use the officinal agaric for soap. Other fungi possess a juice so acrid in their raw state as immediately to blister the tongue, as I once experienced on tasting a minute drop of the juice of a large mushroom, which on breaking the hat poured out a yellow juice, which became purple or blue in a few seconds of time on its being exposed to the air; which I believed to be the fungus *deliciosus* of Linneus; the acrimony of which might never-

thelefs probably be destroyed by a boiling heat. And it is also probable; that the common esculent mushroom may sometimes disagree from their being not sufficiently stewed, or by the incautious mixture of some intoxicating fungi along with them.

Otherwise those in common use at our tables appear to supply a wholesome and nutritive food, approaching towards an animal nature. Two or three kinds are said to be eaten in France besides the red-gilled ones which are eaten here; and it is probable many other kinds of fungi might be found agreeable to the palate, and wholesome food, if well boiled, which might destroy their acrimony; and especially those which when broken have simply the agreeable smell of the red-gilled ones in common use; and some of these, I suppose, might be eaten raw without injury, as many people eat the red gilled ones.

Besides some mushrooms with white gills, which when broken had the grateful scent of the common red-gilled mushroom, and which were said to be more delicious, I have known the *peziza auricula*, or ear-fungus, which was formerly an article of the *materia medica* under the name of Jew's ear, to be stewed and eaten in considerable quantity with impunity; and was esteemed an agreeable article at the supper-table. And as this was esteemed a pernicious genus of fungi by Clusius, it is probable, that many other funguses might lose their acrimony by the heat of stewing, and become wholesome and agreeable food; which are at present in disuse from their disagreeable acrimony in their raw state, or from the bad character they have accidentally acquired.

It should be added, that though those plants, which are supposed to possess an alkalescent property, and to be liable to putrefaction sooner than other vegetables, lose a part of their acrimony by a boiling heat, as water-creffes, cabbages, onions; yet that plants, whose acrimony is of a different kind, as ginger, capsicum, arum, do not become much milder by boiling. I this morning directed some leaves
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of common spotted arum, and of arum ariflarum to be boiled, and on tasting them found my tongue and lips almost excoriated. The nature of this kind of acrimony has not been fufficiently inveftigated by the chemifts, but probably depends on a fixed effential oil.

III. *Barks.*

1. The barks of the trunks of trees are fimilar to thofe of their roots, and may be efteemed a part of them, as they confift of an intertexture of the veffels, which defcend from the plume of each individual bud to the radicle of it, and conftitute its caudex. The bark nevertheless of the root is furnifhed with lymphatics to abforb water and nutritious juices from the earth, and is covered with a moifter cuticle; while the bark of the ftem is furnifhed with lymphatics to abforb moiſture from the air, and is covered with a drier cuticle; the latter reſembling the external ſkin of animals, and the lymphatics, which open upon it; and the former reſembling the mucous membrane of the ftomach, and its lacteals.

As the ſap-juice riſes in all deciduous trees during the vernal months to expand their foliage, though probably in greater quantity in ſome trees than in others, it muſt conſiſt not only of ſugar and mucilage, as in the maple and birch, but of various other ingredients in different trees, which have not been attended to; as appears from the taſte of their young leaves, as of oak or aſh. And as ſome of theſe materials reſide in the roots and ſap-wood or alburnum, ſo others of them may perhaps reſide in the bark, where they have been depoſited during the preceding ſummer, and become lignified by the warmth of the ſpring, or diſſolved by the moiſture abſorbed from the earth and air, and conveyed upwards to the opening buds; whence it is evident, that the barks of trees ſhould be taken off for uſe in winter or in early ſpring, before their buds begin to expand; as then a part of theſe nutritious juices, or of the other materials, which are required for medicines, or in the arts of dying and tan-

ning, are in part expended on the young leaves; which generally possess the taste and qualities of the bark, though in a less degree.

It may nevertheless be observed, that all these astringent, or other materials, may reside in the alburnum of the trunk or roots of all perennial vegetables, as well as in their barks; because the young leaves, which pullulate on decorticated oaks, have the same bitter flavour as the leaves on those, which have not been decorticated; which may in part be derived from the bark of the root, which is still in the ground, and be carried up the vessels of the sap-wood to the new buds.

2. Hence the bark of oak-trees should be taken off during the winter; but when the sap-juice residing or ascending in the vessels of the alburnum becomes more liquefied by the warmth of the spring, or is mixed with more moisture, and pushed up with great force by the absorbent vessels of the roots, it oozes out in some degree between the alburnum and the bark; and thus the bark becomes so much more readily separated from the sap-wood; whence this business is generally done early in the spring, and should be performed as soon as this facility of detaching the bark appears, as mentioned in Sect. III. 5; because this process of the germination of the buds continues to injure the bark, whether the tree be cut down or not; as the buds expand their foliage on new felled trees, as they lie on the ground.

3. The interior barks of some trees, like the alburnum or roots above described, contain much mucilaginous or nutritious matter; as the bark of elm, ulmus, and of holly, ilex; and probably of all those trees or shrubs which are armed with thorns or prickles, which are designed to prevent the depredations of animals on them, as the hawthorn, gooseberry, and gorse, cretægus, ribes grossularia, ulex. The internal barks of these vegetables may be conceived to be their alburnum less indurated, and might probably all be used as food for ourselves or other animals in years of scarcity, or for the purpose of fermentation; as I doubt not but the inner bark of elm-trees, ulmus,

mus, detracted in the spring by being boiled in water might be converted by the addition of yeast into small beer, as well as the alburnum of the maple and birch, *acer et betula*; all which are now suffered to be eaten by insects when those trees are felled.

For the sugar, which is extracted from the vernal sap-juice of the maple and birch, as well as that found in the manna-ash, *fraxinus ornus*, seems to reside during the winter months in the root or alburnum, rather than in the bark properly so called; and to become liquefied, as above mentioned, by the warmth of the spring, or dissolved by the moisture absorbed from the earth, and conveyed to the opening buds; but resides solely in the roots of perennial herbaceous plants; and in the economy of grasses, and I suppose of the sugarcane, it is deposited at the bottom of each joint, which is properly the root of the stem above it, as shewn in Sect. IX. 3. 1.

Of these the bark of the holly not only yields a nutritious mucilage, and thus supplies much provender to the deer and cattle in Needwood-forest by the branches being cut off, and strewed upon the ground, in severe seasons of frost and snow; but contains a resinous material, which is obtained by boiling the bark, and washing away the other parts of it. This resinous material possesses a great adhesiveness to feathers and other dry porous bodies, and has hence obtained the name of bird-lime, and much resembles the caoutchouc or elastic resin brought from South America, and also resembles a fossil elastic bitumen found near Matlock in Derbyshire, both in its elasticity and inflammability. Hollies may be worth cultivating for this material besides the uses of their wood, as I was informed, that thirty years ago a person, who purchased a wood in Yorkshire, sold to a Dutch merchant the bird-lime prepared from the bark of the numerous hollies for nearly the whole sum given for the wood; which if it could be hardened might probably be sold for the elastic resin above mentioned. Whether this resembles the nutritive resinous material
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found in wheat flour, when the mucilage and starch are washed from it, might be worth inquiry, as mentioned in Sect. VI. 8. 5.

4. Other barks contain bitter, resinous, aromatic, or acrid materials, which supply the shops of medicine, as peruvian bark, cascarilla, cinnamon, and were designed by nature to protect those vegetables from the depredations of quadrupeds or insects. Hence many trees, and even the wood of them, after it is dried, and made into domestic furniture, is never devoured by worms, as the mahogany, cedar, cypress; and hence many plants, as the foxglove, digitalis, houndstongue, cynoglossum, henbane, hyosciamus, and many trees, are not devoured by any animals; as their juices would be poisonous to them, or much disagree with their stomachs, if their disgusting flavours to the nose or palate did not prevent their eating them. The same defence of the vegetable kingdom from human digestion, except those which have in long process of time been selected and cultivated, appears from the relation of some unfortunate shipwrecked travellers, who have passed some hundred of miles along uninhabited countries almost without finding an esculent vegetable production.

5. Other barks contain restraining or colouring particles, employed in the arts of dying and tanning, as berberry, oak, and ash, berberies, quercus, fraxinus. The art of tanning consists in filling the pores of the animal mucous membrane with these restraining particles found in some vegetables, which are believed to possess a quality of shortening animal fibres. Thus when a long hair is immersed some time in a solution of the bark of oak, or of the galls produced on its leaves by the punctures of insects, the hair is said to be shortened. Whether this process be occasioned by chemical coagulation of the mucus, of which these fibres totally or in part consist, or by capillary attraction tending to distend these fibres in breadth, and thus to shorten them, as a twisted string is shortened by moisture, has not yet been well investigated. By thus impregnating the pores of animal skins with vegetable particles, they become less

liable to putrefaction, as consisting of a mixture of animal and vegetable matter, as well as much better adapted to many domestic or mechanical purposes.

The art of dying consists likewise in impregnating the pores of dry substances with a solution of the colouring matter extracted from vegetables by the capillary attraction of those pores to the coloured solution. And secondly, by a chemical change of those colouring particles after they have been imbibed, and the water of the solution exhaled, by again steeping them in another solution, which may chemically affect the former. Thus as green consists of a mixture of blue and yellow, it may be best produced by boiling the material designed to be dyed first in a decoction of one of these colours, as of indigo; and then in that of another, as of the bark of berberry. And as a solution of iron becomes black when mixed with a decoction of oak-galls, by being in part precipitated; it is probable, that the particles of this combination of a solution of iron with refringent matter may be larger than either of those particles separately; and therefore that, if a dry porous substance be immersed first in a decoction of oak-galls, and after being suffered to dry, is then immersed in a solution of iron, the black tinge will penetrate into minuter pores, and thus become more intense, than if the substance had been immersed in the black dye already prepared.

6. Other barks are used for apparel, paper, cordage, and for many mechanical purposes, owing to the strength and tenacity of their fibres, or to the fineness of them; as hemp, cannabis; flax, linum; for the purposes of spinning and weaving; an art invented by Isis, queen of Egypt, who seems first to have cultivated flax; which was brought into Europe from the banks of the Nile. The bark or leaves of the papyrus, a flag of the Nile, was first used for paper; and the bark of the mulberry-tree is still made into cloth at Otaheite and other southern islands.

The art of separating the fibres of the bark of plants, as they consist

sift of the caudexes of buds, or the connecting vessels between the plumules and the radicles of them, is performed by soaking them some weeks in stagnant water ; till the mucous membranes, which connect these fibres, are destroyed by putrefaction ; and afterwards by drying them, and beating off with hammers, what may still adhere.

These fibrous parts of the barks of trees, as they contain no saccharine matter, like the alburnum, are much less liable to decay than the sap-wood, or perhaps than any part of the timber. Maupertuis, who went to Lapland to measure a degree of the meridian, says, that among the numerous trees which lay upon the ground destroyed by age, or blown down by the winds, many birch trees appeared whole, owing to the undecayed state of their bark ; but crumbled into powder on being trod upon ; and that the Swedes took the practice from this of covering their houses with this unperishable bark, on which they sometimes lay soil, and thus possess aerial gardens. *Voyages by Mavor, Vol. XII.*

7. To increase the quantity of bark it must be remembered, that the leaf-buds, or viviparous offspring of trees, as they form new buds, acquire new caudexes extending down into the ground, and thus increase the bark of the stem in thickness ; but the flower buds acquire no new caudexes, but die, as soon as they have ripened their seed, and consequently do not increase the thickness of the bark. Whence one method of increasing the quantity of the bark is to increase the number or vigour of the leaf-buds in contradistinction to the flower-buds, which may be done by pinching off the flowers as soon as they appear ; and as the bark becomes gradually changed into wood, this may be one method also of forwarding the growth of timber trees, as mentioned in the next Section.

8. The method of preserving the bark of trees from moss consists in rubbing off that parasite vegetable in wet weather by means of a hardish brush ; which is said to be used with advantage on the apple-trees in the cyder countries ; and may at the same time give motion

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to the vegetable circulation, or forward the ascent of their juices absorbed by the radical or cortical absorbents. In dry weather the brush should be frequently dipped in water. Washing the barks of wall-trees by a water-engine may also facilitate the protrusion of their buds in dry seasons; and might possibly prevent the canker, if applied to dwarf or aspalier apple trees. Other parasite vegetables must be occasionally destroyed, where they occur, as the lichens, fungi, mistletoes; with the ivies and other climbers, as some kinds of *lonnicera*, *clematis*, and *fumaria*, woodbine, virgin's bower, and fumitory.

9. When a wound is made in the bark so as to expose the alburnum to the air, the upper lip of the wound is liable to grow faster downwards, than the lower one is to grow upwards, owing to the former being supplied directly with nutritive juices secreted from the vegetable blood, after its ventilation, and consequent oxygenation in the leaves; whereas the lower lip only receives those juices laterally by imosculation of vessels. Over these wounds the cuticle is liable to project, and to supply a convenient hiding place for insects, which either eat the new fibres of the growing bark, and perforate the alburnum; or by their moisture, their warmth, and their excrements, contribute to the decay of the alburnum, and prevent the healing of the wound. These dead edges of the projecting bark or cuticle should be nicely cut off, but not so as to wound the living bark.

Plasters of lime, or of tar with sublimate of mercury, have been recommended to preserve the wounded parts from the air, and from moisture, and from insects; but as all these materials are injurious to the fibres of the living bark, they should be used with caution, so as not to touch the edges of the wound, but only to cover the alburnum; for this purpose white lead and boiled oil, mixed into a thick paint, or with the addition of sublimate of mercury, or of arsenic, or of spirit of turpentine, may probably answer the purpose; and may be of real utility on the wounds of those trees, whose wood

contains less acrimony, and is therefore more liable to be bored into and eaten by a large worm or maggot almost as thick as a goose-quill : which I have seen happen to a pear-tree, so as to consume the whole internal wood, till the tree was blown down.

In respect to the caution necessary to be observed in not touching the living edges of the wounded bark with such materials as may injure the tree by their absorption, I remember seeing several young elm trees, which died by their boles having been covered, as I was informed, by quick-lime mixed with cow dung to prevent their being injured by horses ; and I have seen branches of peach and nectarine trees destroyed by sprinkling them, when in leaf, with a slight solution of arsenic, and others with spirit of turpentine.

10. A more curious method of cure is said to have succeeded, where the bark of a tree has recently been torn off even to great extent, and that is by binding the same piece of bark on again, or another piece from the same tree, or from one of a similar nature, nicely adapting the edges of the bark to be applied to the edges of that, which surrounds the wound of the tree, which it is said will coalesce in the same manner, as the vessels of the bark of an ingrafted scion unite with those of the bark of the stock ingrafted on ; which is strictly analogous to the union of inflamed or wounded parts of animal bodies, as in the cure of the hare-lip, or the insertion of the living tooth from one person into the jaw of another, or the facitious noses of Talicotius.

If the bark over the cankered parts of apple-trees could be thus renewed by paring the edges of the mortified bark to the quick, and then nicely applying a piece of healthy bark from an apple-tree of inferior value, and securing it with an elastic bandage, as a shred of flannel, it would be a very valuable discovery.

Another method, where a branch of a valuable tree is in the progress of being destroyed by canker, might be by inclosing the cankered part, and some inches above it, in a garden-pot of earth previously

viously divided, and supported by stakes, and tied together round the branch; which might then strike roots in the earth of the garden-pot, and after some months might be cut off, and planted on the ground, and might thus be preserved, and produce a new tree; which experiment I have this summer tried on two apple-trees, and believe it will succeed.

S E C T. XVIII.

PRODUCTION OF LEAVES AND WOOD.

- I. 1. Leaves are the lungs of Vegetables. Grasses propagated by their roots. Some are viviparous. Joints of grasses are successive vegetables. And their roots. Extract roots of twitch-grass by a scarifier with inclined teeth. Produce root-leaves for grazing, and stem-leaves for hay. Eat down the first stem. Cut grass young for hay. Why young hay is liable to take fire. How to prevent it by straw. Eat low meadows late. Sow rye-grass, trefoil, white clover, for successive herbage. Other grass seeds. Roll them in spring. Effects of frost. Use more water as in rice grounds. Sow thick. Heavy cattle should be stall-fed. How to destroy tussocks. How to make hay. 2. Some root-leaves eaten raw. Others previously boiled. Upper part of some roots and of some stems esculent. Asparagus. Art of cultivation of root-leaves and stem-leaves. Of mulberry-leaves. 3. Etiolation of leaves lessens their acrimony. Etiolated flowers. Etiolated ladies. 4. Aromatic and bitterish leaves used as tea, as of sage. When to be gathered. Tea recommended. 5. Leaves used in medicine. Bog-bean instead of hops. Others for tanning, as oak, ash, and alder leaves. Others for dying, as indigo and woad. 6. Leaves will ferment and may make a kind of beer. II. 1. Wood is produced from leaf-buds. To increase wood moisten the trees. Scratch the bark. How to straighten crooked trees. Pinch off the flowers. 2. To render timber trees tall without knots, or crooked for ship-timber. Willows. Oziers. Sugar-maple. Scotch firs. 3. Preserve wood from lightning, and from wood-peckers. 4. Woods differ in colour. Used in dying. Differ in medical and chemical properties. 5. Oak corrodes lead. Sap-wood rots under lead. How prevented. Whence the mysteries of Free Masonry. 6. Woods differ in their hardness and smoothness. Blocks for printing. 7. In their durability as cypress. Alder for piles. 8. In lateral cohesion. Hygrometer. Pendulum. 9. In specific gravity. Rafts of hollow trunks. 10. In elasticity. Bows. 11. How to transplant large trees. How

to prop them. 12. Time of felling timber after barking it. The concentric rings of timber. 13. Pith is brain. Does not communicate from bud to bud. Sagoe from artichoke. From elder. 14. Boundary to the growth of trees. Not to coralline rocks.

I. Of Leaves.

I. The buds of plants have already been shewn to be individual vegetable beings, and the leaves to constitute the lungs of each individual bud. And lastly, that the new bud in the bosom of each leaf is the offspring from the caudex of that old bud, of which the leaf constitutes the lungs.

The leaves of grasses are of great consequence, as they nourish many of our domestic quadrupeds; the cultivation of grasses has therefore been much attended to. Many of these propagate themselves more by their roots than by their seed; especially where their stems are perpetually destroyed by the grazing of cattle, sheep, or geese; and some of them are said to be viviparous, as the *festuca dumetorum*, or fescue grass; that is, that they bear bulbs on their stems after flowering instead of seeds, which in time drop off, and strike root into the ground, like the *polygonum viviparum*, and the *allium magicum*; which circumstance is said to obtain in many alpine grasses, whose seeds are annually devoured by small birds.

The stems of the grasses consist in general of joint above joint without lateral branches; each joint of which seems to be a successive plant growing on the preceding one, and generated in the bosom of the leaf, which surrounds it; the stem may therefore be esteemed a succession of leaf-buds, till at length a flower-bud is produced on the summit, as shewn in Sect. IX. 3. 1. In some grasses, as the *agrostis canina*, or *triticum repens*, dog's-grass, twitch-grass, or couch-grass, the root consists of joints as well as the stem; which may be considered as separate individual plants, like the bulbs of potatoes, as every joint of these roots will grow into a new plant to the great

great annoyance of the agricultor, which, when the ground is not hard, may be best, I believe, drawn out by a deep harrow, or by Mr. Cook's scarifier; as a plough turns them over under the soil, as it breaks them, and thus much increases their number by in a manner transplanting them. The teeth of the harrow, or scarifier, should be inclined forwards towards the horse for the purpose of lifting up the roots, and that it may not too easily rise out of the soil; and it should be fixed by wedges or screw-nuts to the wooden frame for the purpose of occasionally lengthening them to adapt them to different soils, as the roots pierce deeper into less tenacious soils than into clayey ones.

Hence it appears, that a plant of grass consists not only of a tuft of leaves surrounding the root, but that the three or four lower joints of the stem, as of a wheat-straw, are so many successive leaf-buds, which are generated by the caudex of the leaf, which surrounds each joint, and precede the flower-bud at the summit; and that hence with the design of producing much herbage for cattle, the propagation of new leaves from the root is principally to be attended to; but with the design of producing hay, or winter fodder, the leaf-buds of the stem are principally to be attended to.

For the former of these purposes the stem of grass should be eaten down as soon as it rises; whence more grass leaves will arise from the root; as is well known to those who eat down the first stem of wheat, when it is too luxuriant. For the second purpose the leaf-buds, which constitute the stems of grass, should be cut down, before the flower-stem at the summit has begun to ripen its seeds; as at that time the sweet juice lodged in the joint below the flower-stem becomes expended on the seed; and the stem becomes converted into straw rather than into hay.

From hence it is readily understood, why those pastures, which are perpetually grazed, are so much thicker or closer crowded with grass roots than those, which are annually mowed; and why grass cut

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young

young makes so much sweeter and more nutritive hay than that, which has ripened and shed its seed. And lastly, why the hay from grafs cut young is so much more liable to take fire, if ricked too moist; because the greater quantity of sugar in the joints of the stems produces so violent a fermentation, when it has sufficient water to dissolve it, that it generates so much heat as to burst into flame. This might best be prevented, where chopped straw is designed to be given to horses along with their hay, by laying alternately in the haystack a stratum of new hay and a stratum of straw, or of clover and straw; whence the rapid fermentation, which occasions combustion, may be prevented, and the straw may be rendered easier of digestion by being impregnated with the fermentative infection, or yeast, of the fermenting hay.

The art of increasing the quantity of leaves round the roots of grasses consists in eating off the central stems by sheep, or horses, or cattle, early in the season, as above mentioned; whence new ones are produced around the first joint of the stem thus bitten off, and from the distant horizontal root-wires of such grasses, as produce them. In low meadows it is hence doubly profitable to eat down the early grafs till about the middle of May, as in moist situations there is no danger but a crop of hay will succeed; which by this method will be finer and more copious; and at the same time some weeks provender of hay will have been saved by the use of the early grafs.

On land intended for pasture, as for sheep, many people advise to sow three kinds of vegetables, which may in some measure succeed each other in their growth. Mr. Parkinson sows four bushels of the seed of rye-grass, *lolium perenne*, ten pounds of trefoil seed, *trifolium pratense*, and ten of white clover, *trifolium repens*, on every acre; and adds, that the rye-grass should be eaten early, while the white clover is still concealed in the ground, and the trefoil makes only some small appearance. That when the rye-grass is eaten down
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the trefoil springs up, and becomes food for the sheep; after which the white clover succeeds; and after this is consumed, the rye-grass again springs up, and supplies food during the winter months, if the weather proves tolerably mild; and he further asserts, that a third more of sheep at least may be thus nourished than by any other means. Experienced Farmer, Vol. I. p. 88.

For the production of a meadow much superior to those commonly seen Mr. Curtis recommends six kinds of grass and two of clover to be sowed; the seeds are to be mixed together in the following proportions. Meadow foxtail, *alopecurus pratensis*, one pint; meadow fescue, *festuca pratensis*, one pint; smooth stalked meadow-grass, *poa pratensis*, half a pint; rough stalked meadow-grass, *poa trivialis*, half a pint; crested dog's-tail, *cynosurus cristatus*, a quarter of a pint; sweet-scented vernal grass, *anthoxanthum odoratum*, a quarter of a pint; Dutch clover, *trifolium repens*, half a pint; red clover, *trifolium pratense*, half a pint; these seeds are to be mixed together, and about three bushels to be sown on an acre in rows for the convenience of hoeing them. About the end of August or beginning of September they should be occasionally weeded and thinned, and rolled in the spring, to press down into the ground such roots as may have been raised by the frost.

Mr. Curtis thinks that meadow foxtail and rough stalked meadow-grass suit moist soils the best; and that the smooth stalked meadow-grass and crested dog's-tail suit dry pastures; and lastly, that the meadow fescue, and the sweet-scented vernal grass, suit land either moist or moderately dry; and gives the following order of their times of flowering. 1. Sweet-scented vernal. 2. Meadow foxtail. 3. Smooth stalked meadow-grass. 4. Rough stalked meadow-grass. 5. Meadow fescue. 6. Crested dog's-tail. See Hall's Encycloped. Art. Agriculture.

Not only new sown grasses designed for meadows, but the larger grasses, which have the names of corn, as wheat, oats, barley, may be advantageously rolled, when dry, after frost, which by expanding the
water

water in moist soils lessens the cavities, which are occupied by roots; and as roots or their branches are in general conical, they become pushed upwards; and such as are loose rise quite out of the ground, as is often seen to happen to the roots of the strawberries, when a frosty night has occurred soon after their being transplanted. After a slight frost the larger pebbles of a gravel walk are seen below the surface, as if they had sunk downwards during the night; whereas this is owing to a similar cause, the expansion of the moist soil or gravel an inch deep; but as the frost had not penetrated so low as to swell the ground beneath the large pebbles, these had not been lifted up like the smaller ones, or the wet sand.

Secondly, both to increase the quantity of leaves round the root, and to increase the size or vigour, as well perhaps as the number, of leaf-buds on the stem, a greater supply of water than usual, where it can be done, would be advantageous; as is done to the rice-grounds in warm countries in the early part of its growth, and as in flooding our own meadows occasionally in the vernal months. Thus very moist seasons are well known to forward the luxuriant growth of the herbage, and stems, in the cultivation of wheat, and to render the ears later, and less prolific.

Where plants are sown for the purpose of consuming the first foliage, as grasses or saint-foin, the seed should be sown thicker, than where the plant is grown for the purpose of producing seeds, as in wheat or peas; because the quantity of the first foliage will be greater in respect to number; and the central parts of the tussocks, as is often seen in wheat and peas, when sown too thick, will rise two or three inches higher in their contest for light and air, like the trees of thick planted woods; and will hence produce a forwarder pasture as well as a more copious one.

To which should be added, that the plants with succulent stems, as saint-foin, lucern, red clover, receive so much injury from the trampling of heavy cattle, that they should be mowed, and given to

cows and horses in their stalls; which should nevertheless have a yard or fold occasionally to run into with the convenience of water; and if straw be chopped along with this green food, it might be a cheap and a salutary addition.

Where a piece of grass land is overrun with tussocks of four grass, which often happens near towns, I have been informed, that lime or coal-ashes spread on them would render the grass sweeter, so that horses or cattle would eat it. But I suppose the more certain and advantageous management would consist in mowing it frequently, and giving it to the horses or cattle in the stable or stall; as I believe they will eat it greedily after it has been a few hours withered, and thus the land will not only yield more provender at present, but after a few mowings a sweeter grass will rise in the place of that which was of a bad kind, or of too luxuriant growth; for which purpose it should be mowed as near the ground as may be; or if it be frequently mowed during the summer, and left on the ground, some cattle will eat it, when it is withered to a certain degree; by which the disagreeable flavour of it is probably lessened or destroyed.

The art of making hay consists in evaporating about two thirds of the weight of it, as observed by Young and Ruckert. Dr. Hales found a sun-flower plant, which weighed forty-eight ounces to lose thirty-six ounces by drying in the air during thirty days; and consequently to have lost three fourths of its weight. Vegetables to appearance perfectly dry contain three fifths or three fourths of their weight of water; a part of which water Mr. Kirwan thinks is not in its liquid state, but that it is by a loss of much of its specific heat in a great measure solidified. Kirwan on Manures, p. 37. Thus when water is thrown on fresh quick-lime, a part of it unites with the lime, and becomes solid, giving out much heat; which converts another part of it into steam, as mentioned in Sect. X. 4. 4.

There are two methods of making hay practised in different parts

of the country. In the more southern counties the swarths are not turned over or scattered for a day, or two, or three, but remain as they were left by the scythe. In the more northern counties the hay-makers follow the mowers, and scatter the grafs immediately, or on the succeeding day. Perhaps a method between these may in general better suit this climate.

Herbs collected for medicinal purposes, as well as flowers, should be dried in the shade; otherwise they become bleached, and lose both their colour and their odour, by too great insolation, and exhalation. Now if the swarth of cut grafs be only turned over once a day for three or four days, the internal parts of it may be said to be dried in the shade; and afterwards if it be spread over the ground for only a few hours on a fine day, I suppose it would become dry enough to stack, and have lost considerably less of its nutritive quality. Some advise a chimney to be left in the center of a stack to prevent the hay taking fire, but there should then also be culverts under the stack to supply that chimney with air; which may be made by cutting three or four trenches in the earth, and covering them with boards or sticks with their apertures exposed to the wind in all directions. Perhaps the best way would be to make the stack narrow and long, and bent into a semicircle or crescent to enable them the better to resist the winds, instead of round or square, though a greater surface would indeed be afterwards exposed to the weather, and in some degree injured, by this mode of construction.

When the grafs is spread uniformly over the whole meadow, which is called *tedding*, it will sooner dry, as so much larger a surface of it is exposed to the wind and sun; but it should certainly be put into small cocks or wind-rows at night, especially if the weather be moist; because it will otherwise receive much dirt and slime from the innumerable worms, which rise out of the ground always in moist warm nights, and generally when the surface is covered with moist

grafs at all seasons; and when they retreat into their subterranean mansions in the morning, they are liable to draw in the ends of the grafs to stop up the apertures of their holes, and by that means prevent the centipes from following them into their homes, and destroying them. See *Zoonomia*, Vol. I. Sect. XVI. 16. Whence much of the new hay becomes injured by the foil, they previously push before them out of their mines, and by that which adheres to the grafs, which was drawn in to stop the apertures of them, as well as by the slime, which they leave behind them on the new hay, which they pass through or over.

On this account hay-cocks should be made as high as may be in proportion to their base, that less surface may be in contact with the ground, as well as that a greater surface may be exposed to the air for a quicker exhalation of its moisture, and for the purpose of the better securing it from accidental showers.

In wet seasons, I suspect, the best method must consist in turning over the rows of swarth every day or every alternate day, or making it into small cocks, and turning them over in the same manner, that the rain may not injure the whole of it by passing perpetually through it, and washing away its saccharine and mucilaginous fluids; and also that the part next the ground, and the central parts of the cock or swarth, may not pass into fermentation and putrefaction. And lastly, when it can be put into tall cocks, as the weather becomes drier, it will not only sooner exhale its moisture by the contact of the atmosphere, but a beginning fermentation will set at liberty some degree of heat, and thus contribute to dry it by increasing the evaporation; as the great heat generated in hay-stacks which have been finished but one day or two, assists much to dry the whole stack in moist seasons, as is seen by the dense steam, which arises from them.

2. Many root-leaves are consumed at our tables either in their raw state, as those of water-cress, *silybrium nasturtium*, lettuce, *lactuca sativa*, mustard, *sinapis*, celery, *apium*; many others are previously
boiled

boiled to diminish their acrimony, and to coagulate their mucilage, as the root-leaves of spinach, spinacia, of cabbage, brassica oleracea, and even of turnips, brassica rapa; along with these stem-leaves of many plants the flower-buds at their summits are eaten, as those of mercury, mercurialis, and of some of the cabbage kind called brocoli, brassica italica.

Many of these leaves not only consist of a respiratory organ, but at the lower parts of them especially, or in their stalks, there exists a reservoir of nutriment for the rising flower-stem or for the ripening seed, as in rhubarb leaves, and in cabbage leaves, which is similar to that in the roots of other herbaceous plants, and which renders them both palatable and nutritive. Most of these concentric leaves are situated in contact with the earth, as those of lettuces, lactuca, and fassia, tragopogon. But others of them, as the cabbages, are placed on a stem at some distance from the ground; in the former the upper part of the root or caudex is palatable and nutritious, as well as the lower part of the leaves; and some of them are of superior flavour when boiled. In the latter the reservoir of nutriment for the future flower-stem and seed consists in the lower part of the ribs of the concentric foliage, as in the concentric leaves or lamina, which cover the bulb of the onion, or even in the stalks, as in cabbages, and artichoke, which are therefore not only esculent, but palatable and nutritive.

Other leaves are eaten in their early state along with the stem, which they surround, as asparagus, and the young shoots of spinach, and of some kinds of brocoli, and of mercury; which last are sometimes suffered to shew their flowers before they come to our tables, and are then treated of in Sect. XIX.

The art of cultivating all these consists in supplying them with abundant carbonic earth, and with abundant moisture, as these are more friendly to the luxuriant growth of root-leaves or stem-leaves, than to the production of the flowers, or ripening of the seeds, as ap-
pears

pears by the too luxuriant growth both of herbaceous plants and of fruit trees in moist seasons.

Another method of forwarding the growth of the new leaves and stem-shoots of perennial herbaceous plants, as of asparagus, is annually to loosen or turn over the earth around and above the roots, for the purpose of admitting air into its cells or cavities to convert a part of the manure or carbonaceous soil, with which they have been supplied, into ammonia, or into carbonic acid, and thus both to afford them warmth and nutriment.

Add to this, that the leaves of trees may be increased in size by lopping off the branches, by which means the remaining buds acquire more nutriment; the black mulberry tree is thus kept low, and formed into extensive shrubberies in China for the purpose of feeding silkworms, as observed by sir G. Staunton, who thinks the leaves are thus rendered both larger and more succulent; and adds, that the ash-tree is also sometimes used for the same purpose.

3. Another method of destroying the too great acrimony of leaves, besides that of boiling them, consists in secluding them from light, and is termed etiolation. This is chiefly practised on cellery, apium, by earthing it up nearly to the top of the plant; and on sea-kale, *crambe maritima*, by covering the plant entirely with horse-litter or straw, as described in Sect. XIV. 3. 3; and on lettuces, and endive, by tying together the root-leaves with a bandage.

In many plants the central bud during its early growth seems to be naturally in a state of etiolation, as it is excluded from the light by the curvature of the surrounding foliage, as in cabbages, and particularly in some species of aloe, which are said to consume nearly a century in opening their numerous concentric foliage. These etiolated leaves, like flowers before the calyx is opened, are white; and the leaves become green, or the flowers of many other colours, when exposed to the light, as explained in Sect. XIII. 1. 3. It is probable that the foliage of many other plants might be rendered esculent by
thus

thus destroying their acrimony, and decreasing the tenacity of their fibres by etiolation, as well as the leaves of celery, apium; and cardoon, cinara; and of endive, cichorium endivia.

A seclusion from the sun's light and from air has an effect somewhat similar on animal bodies, rendering them pale and weak, as may be seen in the etiolated young ladies of some boarding schools; and in those who pass their waking hours in unventilated parlours during more than half the night.

4. Other vegetable foliage has been brought into very extensive use infused in hot water for its agreeable aromatic or bitterish flavour, as those of foreign tea, thea; and of the ash, fraxinus, of our own island, the leaves of which were collected, before they became expanded, and sold after being dried for the inferior kind of Bohea tea in so great quantity as to occasion an act of parliament to be passed about forty years ago to lay a fine on any one, who should have accumulated more than fifty pounds of ash leaves, which were not the produce of his own trees. The leaves of many other of our domestic vegetables, as of mint, balm, and sage, mentha, melissa, salvia, have been infused in hot water as an agreeable diluent beverage both in health and sickness; the last of which, the sage, possesses a very pleasant aromatic flavour; and if the infusion be poured from the leaves, before it has acquired too much of the bitter flavour, it is very grateful to the palate or stomach, and has been esteemed salubrious from high antiquity to the present times, whence the line of Horace:

Cur moriatur homō, cui salvia crescit in horto?

All these infusions become nutritive, when drank with cream and sugar, and have certainly contributed to the health of the inhabitants of this island by decreasing the potation of fermented or spirituous liquors; and to their morality by more frequently mixing the ladies and gentlemen in the same society.

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The leaves of these plants, as well as the aromatic or balsamic buds of some other plants, as of *myrica*, *gale*; of *tacamahaca*, *populus balsamifera*; of balm of *Gilead*, *amyris giliadensis*, and many others, should be gathered at the time of their greatest fragrance, as the essential oils, which constitute their odorous exhalation, perpetually evaporate, as our sense of smell informs us; and were apparently for the purpose of defending the plants from the depredation of insects in their state of infancy.

5. Other leaves have been used for medicinal purposes, and for the arts of dying and tanning, like the barks before mentioned; as the leaves of *carduus benedictus*, *cnicus acarna*, as an emetic; those of foxglove, *digitalis purpurea*, as an absorbent in *anasarca*; those of bog-bean, *menyanthes trifoliata*, as a corroborant; which last might probably supply the place of hops, *humulus lupulus*, in the breweries of malt-liquors; and as it might be plentifully cultivated on boggy grounds, which are not at present used for other purposes, might be a cheaper bitter to the consumer, and save to the public much more fertile soil for the cultivation of corn or other valuable vegetables.

The leaves of *teucrium scorodonia*, wood-sage, are as bitter as those of *menyanthes*, bog-bean, and have been used with success, as I have witnessed, in the cure of agues; and, as it grows on dry barren soils, might possibly be cultivated to supply the place of peruvian bark in some diseases, or to supply the use of hops in the breweries of malt-liquor.

The leaves of oak-trees, *quercus robur*, and of ash-trees, *fraxinus excelsior*, and of alder, *betula alnus*, even after they drop spontaneously in the autumn, are said to serve the purpose of tanning animal membranes, like the barks of the same trees spoken of in Sect. XVII. 3. 5; and for the purposes of dying, the leaves of indigo, *indigofera tinctoria*; and of wood, *isatis tinctoria*; and of weld, *reseda luteola*,

have been much cultivated, and extensively used; and a species of polygonum is said to be much cultivated in China for the same purposes as indigofera by sir G. Staunton; to which may be added the foliage of lichen fructicosus, or archil, a whitish lichen brought from the rocks of the Canary Islands, which gives a beautiful bloom to other colours, but is itself very fugitive. Linneus asserts in the Swedish Transactions, that this archil moss is to be found on the western coasts of England; and it is said, that the archil is now prepared by Messrs. Gordens at Leith near Edinburgh from a species found in the Highlands of Scotland. Encyclopedia Britannica. Art. Archil. The manner of cultivation and of the extraction of the colouring matter from the leaves of these plants may be also seen in Bomare's Dictionnaire Raisonne, and in Chambers's Encyclopedia. It is probable, that many other plants, as hedyсарum, saintfoin, or the broad thick leaves of phytolacca, might yield a similar material to that of indigo, woad, and weld, if properly cultivated and prepared, as well as other kinds of mosses or lichens to that above mentioned.

The green colour of perhaps all vegetables, as well as of those from which indigo and woad are produced, is owing to the blue fecula, which has been obtained for the dyers principally from those plants; and to a yellow material, which is more fugitive or more easily decomposed, which yellow may possibly be owing to iron. This blue fecula is simply obtained from indigo, as it subsides from the fluid, in which the plant is suffered to ferment; and is obtained from woad along with the cellular parts of the leaves during their fermentation in water, and beaten into a mass. It is probable that the bluest kinds of vegetables may contain the most of this fecula.

For domestic purposes the juice of the sage-leaf, *salvia officinalis*, has been used both to give colour and flavour to cheese; and the juice of spinach is employed, I am informed, to colour the green usquebaugh, a favourite dram with the Irish vulgar. And it is probable, that the leaf of the vine, which bears purple grapes, might give

a similar colour and astringent taste to our domestic wines, as the skin of the same grape gives to the foreign wines made from it; since the leaves of this vine always become quite red in autumn, before they fall, probably by the concentration of their acidity, as their water evaporates unsupplied; as all blue vegetable juices become green by an admixture of alkali, and red by that of an acid.

6. Another use for which leaves are collected by some gardeners, as they fall in autumn from any kinds of trees, is for the production of heat by fermentation in hot-houses, or melon-frames, instead of oak-bark, after its bitter particles have been much extracted by the tanner; and it is probable, that many leaves might be selected, as they will thus undergo fermentation, which might afford a spirituous drink like small beer without any disagreeable flavour, or unwholesome material; which now serve only for manure when gathered into heaps, or by their slow decay on arable lands; or encumber the grass lands, they fall upon.

II. *Of Woods.*

1. The leaf-buds of trees producing a viviparous offspring acquire new caudexes, extending from the branches to the ground, and the intertexture of these caudexes forms the new bark over the old one. But the flower-buds acquire no new caudexes down the bark, as their oviparous progeny does not adhere to the side of the parent bud, but falls down when mature, and strikes root into the soil.

Now as the bark of trees is thus produced along with the leaf-buds, and as it annually becomes alburnum or sap-wood; and that sap-wood gradually loses all vegetable life, and becomes heart-wood, it follows, that the art of forwarding the growth of the wood of trees must consist in producing and nourishing the leaf-buds.

For this purpose the roots of trees should be supplied with rather more water, than they generally possess in their most natural state, or the branches should be sprinkled by a water-engine; as moisture facilitates.

cilitates the production of the new caudexes of the leaf-buds probably by lessening the cohesion of the cuticle, or mechanically relaxing it, like the cuticle of our hands when long soaked in water, as well as by supplying them with more nutriment.

It may sometimes occur, that the cuticle of trees, or exterior bark, may adhere too strongly, and by not opening in cracks confine the growth, or prevent the production of the caudexes of the new buds. There is annually a new cuticle produced beneath the old ones, as well as a new bark above the old ones; hence some trees have as many cuticles as they are years old, others cast them more easily, as a snake casts its cuticle. When a number of cuticles thus exist one over another, it is useful to scratch them longitudinally, which will admit the new bark beneath, consisting of the caudexes of the various buds to swell out, and form a line more prominent than the other parts of the trunk of the tree. If crooked young trees be thus scratched internally in respect to the curvature, and this repeatedly, I am informed, that they will gradually become straight, by thus encouraging the growth within the curvature more than on its convex side.

Another method of increasing the number and vigour of the leaf-buds, and in consequence of enlarging the wood of a tree, consists in pinching off the flowers, as soon as they appear; as the nourishment is thus supplied to the leaf-buds by the inosculation of the vessels of the bark, which otherwise would have been expended on the flowers, fruit, and seeds. The truth of this circumstance is not only countenanced by gardeners, who pull off the flowers of fruit-trees lately planted to encourage their growth, but also from the appearance of sickly trees; which are liable to perish, when in flower. In this case it often happens, that, after the flowers fade, some of the leaf-buds continue to expand, or new ones put out, owing to the supply of nutriment not being now expended on the flowers.

2. As tall timber trees without branches, and consequent knots in the timber, are most valuable except for ship-building; this may be

certainly effected by planting them near each other; as then the powerful contest with each other for light and air propels them upwards, instead of producing many lateral branches; as may be seen in many woods, which have not been too much thinned. For this purpose some have planted trees of less value though of quicker growth, as pines, amongst oaks; which may be pruned or lopped, if they shade the oaks too much, and may be finally removed, when the oaks are crowded by them; whence single trees seldom grow so tall as those in woods, and appear stunted, as it is called; which is generally ascribed to the cold seasons, or to their being exposed more to the winds; which may perhaps sometimes happen in this northern climate; or where trees are exposed to insalubrious air, as near the sea; or exist in colder situations, as on the summits of mountains.

Something similar to this may be seen in tussocks of grass, or where too many seeds of wheat have been sown near together. The central part of the knot of wheat or grass grows much taller than the external part, so as to give it a conical figure; which has been by some ascribed to the central part having been sheltered from the cold by the external ring, but is more generally owing to the struggle of the internal stems for the acquisition of light and air.

The Society of Agriculture at Copenhagen has proposed prizes concerning the cultivation of timber for ship-building. One question is, whether the necessary form and degree of flexion can by any means be given to growing timber without injuring it? This I imagine may be done by annually scratching the external bark or cuticle either longitudinally or horizontally on the south side of the part of a tree, which is wished to be curved, as the south side of trees are known to grow faster annually than the north side, as is seen by the greater thickness of the concentric rings of a tree, when felled and sawed into blocks; and because the cuticle bounds the lateral growth of the trunks of trees, as the skin of animals bounds the growth of the

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the cellular parts beneath it ; and hence that side of the tree, where the cuticle or exterior bark is frequently scratched through, will become larger than the other side of the tree, and tend to bend it into a curve with the scratched side outwards. Trees also on the outside rows of woods will spontaneously bend outwards for light and air, and may I suspect be more easily formed into proper curves by the method above proposed. And where trees in a wood are at a proper distance from each other, they may forcibly be bent by cordage towards each other, and then by wounding the exterior and interior bark longitudinally, or perhaps horizontally also on the exterior side of the curved part of the tree, they may be brought into almost any degree of flexure, which they will afterwards preserve as the tree advances.

Some of the quicker growing trees may be more valuable to the planter than oaks, and some in different soils are more valuable than others ; as willow-trees in the hedge-rows in moist grounds are said, if headed once in ten years, on an average to produce each of them one shilling a year. Perhaps the ozier for basket making may be still more advantageous in low grounds ; there is a valuable paper on the planting of them and the choice of the kinds of them in the Transactions of the Society of Arts, Vol. XVI. p. 129, by Mr. Phillips. Perhaps the fugar-maple may also be cultivated in this climate to advantage on many barren commons, as on Cannock Heath. And certainly pines, as Scotch fir, might in these situations succeed astonishingly, as appears by the plantations of Mr. Anson on the barren mountains near his seat in Staffordshire ; and also from the plantations of the marquis of Bath at the foot of Wiltshire Downs near Warminster, whose steward, Mr. Davis, has given a valuable account of the profit of planting Scotch fir in preference to other timber trees ; and finally asserts, “ that although fir-timber is worth individually more per tree than oak or beech of the same size, these trees will nevertheless grow faster and thicker together than any other trees. Four
firs

firs will grow, where but one oak or beech will grow ; for firs are the better, and deciduous trees the worse, for being crowded." I suppose because the branches of the latter are valuable, but the former is injured by the knots left in the trunk, where large branches have existed. *Transf. of Society of Arts, Vol. XVI. p. 126.*

Mr. Davis adds further, I suppose from his own observation, that " the chalk-hills in Hampshire are peculiarly proper for beech ; the flinty loams and clays of the same county for oaks and ash ; the mossy steep sides of the Wiltshire Downs for hazel ; the rugged and almost naked rocks of Mendip in Somersetshire near Chedder produce the lime-tree and the walnut in the greatest luxuriance ; and on the highest parts of the same Mendip hills, where no other tree can stand the sea-breeze, sycamore flourishes as well as in the most fertile vallies. But taking into consideration the general demand of countries, and the peculiarities of different soils, no kind of wood is so generally profitable for planting in coppices as ash." *Ib.*

3. Another thing concerning timber-trees, which ought to be attended to, is the injury, they are liable to receive from lightning ; which, I am informed, is much more frequent than is generally supposed ; insomuch that in felling most woods, especially those which grow in wet situations, very many of the trees are found to be cracked longitudinally to the great injury of the timber ; to prevent this, pointed wires, as thick as a goose quill, should be attached to a few of the tallest trees of all flourishing woods reaching above their summits, as conductors of lightning. Add to this that the holes made by wood-peckers, I am told, are very numerous, and do much injury to the timber of our forests, which can only be prevented by destroying that beautiful and ingenious bird.

4. Woods differ from each other in many respects, and are therefore used for many other purposes besides mechanical ones ; as in colour ; whence particular woods are chosen for their beauty in the construction of the furniture of houses, as rose-wood, aspalathus ;

others are used in the art of dying, as the Campechy wood, hæmatoxylum, and faunders, fantalum, and pterocarpus; and several others. Other woods differ in their medicinal properties, as guaicum, quassia, Campechy wood, and sassafras. Others differ in their chemical properties, affording essential oils, as oleum rhodii, and turpentine or balsams, and tar; and in their restridency, as the oak.

5. The oak probably contains much gallic acid, such as has been extracted from the galls occasioned on their leaves by the punctures of insects; whence oak boards are said to corrode the sheets of lead, which are laid on them, and are hence believed to be improper for the gutture-boards on the roofs of houses. But the sap-wood, or external part of all timber, I suspect, must be improper for this purpose on another account; as, when confined from much air by the sheet of lead over it, it must lie for many months in the year in that state of moisture, which will favour the fermentation of the saccharine matter, which all sap-wood contains; and will thence be subject to the dry rot, as it is called by architects. This may be long prevented by leaving proper holes in the walls on all sides the building immediately under the roof, as has been generally done by those itinerant bodies of architects, who shewed such prodigies of genius in the construction of cathedrals in this island, and all over Europe; and whose secret identifying words, and confederate signs, which were necessary to them in foreign countries, whose language they had not time to acquire, seems to have given origin to the modern mysteries of Free-masonry.

The rot of wood might probably be entirely prevented by soaking dry timber first in lime-water, till it has absorbed as much of it as may be; and then after it is dry by soaking it in a weak solution of vitriolic acid in water; which will unite with the lime already deposited in the pores of the timber, and convert it into gypsum; which I suppose will not only preserve it from decay for many centuries, if

it

it be kept dry, but also render it less inflammable, a circumstance worthy attending to in the construction of wood-built houses. I also conceive that beams so impregnated would be less liable to swag, and boards so prepared less liable to warp. In the immense salt-mines of Hungary many large wooden props, which support the roof, and are perpetually moistened with salt-water trickling down them, are said to have suffered no decay for many centuries.

6. Woods also differ from each other in their hardness, or the general cohesion of their particles, whence one kind of timber has obtained the name of iron-wood, *sideroxylum*. Others differ in the fineness of their constituent fibres, which shew a beautifully smooth polish, when planed, as rose-wood, *aspalathus*.

Where these two properties of hardness and smoothness exist together, as in box, *buxus sempervirens*, the wood must be peculiarly valuable for the purpose of making wooden printing blocks, so well managed at this time by Mr. Bewick of Newcastle in his books of Natural History of Quadrupeds and Birds.

7. Other woods differ in their durability, as cypress, cedar, mahogany, are said to be indistructible by time, or by the depredation of insects. The wood of the cedar of Bermudas, *Juniperus Bermudiana*, in which black-lead pencils are inclosed, is said not to be eaten by either aerial, terrestrial, or marine insects, and is thence used in the West Indies for building vessels, whose bottoms are not penetrated by sea-worms. The unperishable chests, which contain the Egyptian mummies, were of cypress, as well as the coffins in which the Athenians are said by Thucydides to have buried their heroes. The gates at St. Peter's at Rome, which had lasted from the time of Constantine to that of Pope Eugene the fourth, that is eleven hundred years, were of cypress, and had at that time suffered no decay.

Of these some are believed to endure longer in water than others, as alder, *betula alnus*, and is therefore esteemed preferable for piles to guard the banks of rivers. But Mr. Brindly, the conductor of the

grand trunk canal, assured me, that he believed from observation, “that red Riga deal, or pine-wood, would endure as long as oak in all situations,” owing perhaps to its being so full of resin or turpentine.

8. Other woods differ in the degree of the lateral adhesion of their longitudinal fibres, as the fir-wood, or deal, *pinus*, whence the timber readily splits by wedges. As the moisture of the atmosphere is absorbed into the pores of the dry cellular membrane, which connects the longitudinal fibres of these woods, more than into those of the longitudinal fibres themselves, they become much more dilated laterally than extended longitudinally, by the change of a dry atmosphere to a moist one; whence by joining pieces of deal cut cross-wise into a rod of some feet in length, a very sensible creeping hygrometer was made by Mr. Edgeworth, described in the *Botanic Garden*, Vol. II. note on *Impatiens*. And as this wood is not liable to be much extended by low degrees of heat, when it is impregnated with boiling oil, or covered with varnish, to prevent the access of aerial moisture, the pendulums of time-keepers have been constructed of it, which have not perceptibly lengthened in any variations of the heat or moisture of the atmosphere.

9. Another circumstance of great consequence, in which woods differ, is their specific gravity, as many of them will sink in water, as oak after it has been long moistened; and others will swim with much of their contents above water, as deal, and hence have been used for the construction of rafts for the purposes of rude navigation; and which are now said to be constructed in France as engines of war, probably for the design of suddenly landing troops, horses, artillery, and provisions, from the ships of invading armies on dangerous shores, and for the certainty of re-embarking them. These nevertheless can not carry great burthens simply by their specific levity; but if each piece of timber could be made hollow, and rendered water-tight, so as to contain air, which might probably be done by

boring them, and plugging up the ends ; or by joining thick boards together by means of paint and flannel, or caoutchouc, so as to construct long square wooden troughs filled with air, perhaps eight or ten inches diameter within, and twenty or thirty feet long. If the junctions of these could be rendered water-tight, and a number of such hollow trunks could be chained loosely together, and laid cross-wise three or four times over each other, they might carry very large burthens, not easily to be destroyed by storms, or sunk by cannon shot.

10. Another difference of the longitudinal fibres of timber consists in their degree of elasticity, a circumstance of much greater consequence to our ancestors in respect to the art of war than to the present generation ; as their bows for discharging arrows, and the catapult, or engine for throwing stones, depended on the recoil of rods or beams of timber forcibly bent into a curve. For the construction of bows the yew-tree, *taxus*, was used in this island, and was planted in church-yards, probably for the purpose of supplying the youth of the parish with bows, that they might become expert in the use of them ; many of which have acquired extreme old age, and remain to this day.

11. When tall trees are designed to be transplanted for the purpose of ornamenting a pleasure-ground, it is proper to dig a circular trench round them two or three feet deep in the early spring ; whence many new roots will shoot from those, which have their ends cut off, and thus the ball of earth will be better held together, when the tree is removed in the succeeding autumn, and the tree by having previously produced so many more fine absorbent radicles will be more certain to grow in its new situation.

Hence when new grafted fruit-scions on young stocks are designed to remain a few years in the nursery, before they are designed for sale, some provident gardeners I am told transplant them every two years, that the root-fibres may be more numerous in a small compass,

pals, which occasions them to grow, when finally transplanted, with more certainty, and with greater vigour.

As transplanted trees should not be set too deep in the ground, as their growth is then always much checked, as explained in Sect. XV. 2. 4. they generally require some kind of props to prevent them from being overturned, or much shook by the winds, before they have sufficiently extended their roots. As the bark is the only living part of the tree, it is liable to receive much injury from its contusion by the pressure of the props against it, or by the strangulation of the bandage which holds it to them. Hence as the internal wood of a tree is not alive, I remember many years ago, that I fastened one prop by a strong nail to each fruit-tree of a small orchard, which I then planted; and found the tree supported with much less apparent injury than in the usual manner by three props and adapted cordage.

12. The time for felling timber has generally been in the winter season, when labourers could best be spared from other rural employments, and from the architecture of towns; but it was long ago observed by Mr. S. Pepys in a paper published in the *Philosoph. Transact.* Vol. XVII. p. 455, that the best time for felling oaks for ship-building was after having taken off the bark in the early spring, and having suffered the new foliage to put forth and die. For by the pullulation of the new buds the saccharine matter in the sap-wood or alburnum is expended, and it then becomes nearly as hard and durable as the heart-wood, being both less liable to decay, or to be penetrated by insects; which was a curious and ingenious discovery at that time, though the theory was not well understood; the truth of which has now been established, I believe, by the experience of a century.

As the bark of trees annually changes into alburnum or sap-wood, so the alburnum annually changes into lifeless wood; whence the concentric rings, which are seen in the trunks of trees, when they

are felled, are annually produced ; and are said generally to be thicker on that side of the trunk, which grows towards the south, than on the northern side, and thicker in the summers most favourable to vegetation than the contrary. These rings, as they lose their vegetable life, and at the same time a part of their moisture by evaporation, or absorption, gradually become harder and of a darker colour ; inasmuch, that by counting their number, it is said, that not only the age of the tree, but that the mildness or moisture of each summer during the time of its growth may be estimated by the respective thickness of the rings of timber.

13. In the same manner the central pith also loses its vegetable life, probably after the first year ; and then gradually becomes absorbed, or so impregnated with ligneous particles, as not to be distinguished from the surrounding wood. The pith of a young bud so resembles the brain and spinal marrow of animals in respect to its central situation, that it probably gives out nerves to every living fibre of the bud ; though these have yet escaped our eyes and glasses ; and thus furnishes the power of motion, as well as of sensation, to the various parts of the vegetable system. One curious fact, which I have observed, seems to countenance this conjecture ; which is, that the pith of a last year's twig communicates to the leaves on each side of it, but not to the new buds in the bosoms of those leaves ; because those new buds are each an individual being, generated by the caudex of the leaf, and must therefore possess a sensorium of its own. See Sect. I. 8. and IX. 2. 4.

The pith of trees contains much mucilage, as well as the stalks of annual and perennial plants, whether they are hollow or not ; the pith of a palm-tree, *cycas circinalis*, is softened with water, and passed through sieves, and thus forms the sago of our shops ; it is possible the large pith of the stalks of artichokes, *cinara scolymus*, might be manufactured into a similar kind of tasteless mucilage ; and the pith of the young shoots of elder, *sambucus nigra*, might also
possibly

possibly be made into tasteless mucilage, if previously agitated in cold water to wash away any acrid material, as in the preparation of starch.

14. When we contemplate the manner of the production of the internal wood of trees from the induration of the sap-wood, and the annual increase of the sap-wood from the bark, which was previously generated by the caudexes of the numerous buds; there would appear to be no natural boundary to the growth of trees. But that their trunks, though a mile distant from each other, might be enlarged, till they meet together, and cover the whole earth with ligneous mountains, constructed by successive generations of vegetable buds; as some parts of the ocean are crowded with calcareous rocks, fabricated by the successive generations of coralline insects!

A very large tree is described by Mr. Adanson in Africa, which is called by Linneus *Adansonia*, in honour of that philosopher; of which he says the diameter of the trunk frequently exceeds twenty-five feet, and the horizontal branches are from forty-five to fifty-five feet long, and so large, that each branch is equal to the largest tree in Europe. The breadth of the top is from 120 to 150 feet; and one of the roots bared only in part by the washing away of the earth by the river, near which it grew, measured 110 feet long, and yet these stupendous trees do not exceed 70 feet in height. Voyage to Senegal.

And in this country, when the internal wood is gradually detached from the alburnum, as it decays, as in some old hollow oaks and willows, so that it does not destroy the tree by the putrid matter being absorbed, there seems to be no termination of the growth of the external remains of the tree, till the wind blows it down from its want of solid wood to support it. Of this kind of hollow tree a remarkable instance remains in Welbeck Park in Nottinghamshire, through the middle of which a coach is said to have been driven. There is another oak of uncommon dimensions in the forest of Needwood,

called Swilcar oak, celebrated in an unpublished poem by Mr. Mundy, on his leaving that forest, and is there said to be 600 years old.

• But the caudexes of buds, which compose the barks and afterwards the timber of trees, differ from the nests or cells of the coralline insects, which compose their calcareous rocks beneath the waves, in this circumstance. The cells of the coralline insects, like the shells of other sea-animals, become harder by time, changing by flow degrees the phosphoric acid, which they contain, for carbonic acid; and some of them afterwards for siliceous acid, and are thus converted into limestone and flint, and remain eternal monuments of departed animal life.

Whilst the remaining vascular system, after the death of vegetable buds, like the flesh of animals, undergoes in process of time a chemical decomposition, and loses by fermentation and putrefaction both their carbonic and phosphoric acids, which probably gave them their solidity, and crumble into dust; which is seen in the rotten trunks of trees, which lose so much of their carbon as they decay; and also become luminous, when exposed to the air by the escape or production of phosphoric acid. And finally, their other component parts are separated by elutriation, and form morasses; whence coals, iron, clay, and sandstone; all which are found on the lime-rocks, which were previously generated in the ocean, and remain eternal monuments of departed vegetable life. Whence it appears, that a boundary is set to the size of trees by their internal decay, but none to the growth of coral-rocks, which are so formidable in the navigation of the southern ocean.

15. *Question on the cultivation of Timber.*

The political advantage or disadvantage of cultivating timber in this island should be here considered. In the present insane state of
human

human society, when war and its preparations employ the ingenuity and labour of almost all nations; and mankind destroy or enslave each other with as little mercy, as they destroy and enslave the bestial world; and may in time, for what appears to the contrary, return to their savage state, and begin to eat each other again, as seems to have occurred at or before the commencement of almost all civil societies; the first political attention should certainly in this period of human infatuation be employed to strengthen the country, to enable it to repel the invasion of foreign enemies, and to defend its natural rights, when they are infringed by them; but not to attack or invade other nations for any predatory or ambitious purpose. The next important thing should be for this nation to set a great example of justice and humanity to all contending nations, and thence again to introduce truth and virtue into the world with peace and happiness in their train.

Now as the power to resist invasion, and to defend our natural rights, when infringed by foreign enemies, must depend more on the number of men than on the number of trees; there need be no hesitation in determining, that those lands, which can be employed in the present production of vegetable or animal food, should not be occupied in the tedious cultivation of future timber.

But that, as the summits of this country consist principally of a ridge of mountains extending from south to north between the eastern and western seas, as those of the Peak of Derbyshire and the Moorlands of Staffordshire, which are so bleak or so barren as to be totally unfit for the plough or for pasturage, and yet might be employed for raising variety of timbers; which from our great successes in naval engagements may be termed with great propriety, when employed in building ships, the wooden walls of this island: All those unfertile mountains from the extremity of Cornwall to the extremity of Scotland, should be covered with extensive forests of such

such kinds of wood, as experience has shewn them to be capable to sustain, and which may be best adapted to the construction of ships.

16. The following address to Swilcar oak in Needwood forest, a very tall tree, which measures thirteen yards round at its base, and eleven yards round at four feet from the ground, and is believed to be six hundred years old, was written at the end of Mr. Mundy's poem on leaving that forest, and may amuse the weary reader, and conclude this Section.

ADDRESS TO SWILCAR OAK.

Gigantic OAK ! whose wrinkled form hath stood,
 Age after age, the Patriarch of the wood !—
 Thou, who hast seen a thousand springs unfold
 Their ravel'd buds, and dip their flowers in gold;
 Ten thousand times yon moon relight her horn,
 And that bright star of evening gild the morn !—
 Erst, when the Druid-bards with silver hair
 Pour'd round thy trunk the melody of prayer;
 When chiefs and heroës join'd the kneeling throng,
 And choral virgins trill'd the adoring song;
 While harps responsive rung amid the glade,
 And holy echoes thrill'd thy vaulted shade;
 Say, did such dulcet notes arrest thy gales,
 As MUNDY pours along the listening vales ?

Gigantic OAK !—thy hoary head sublime
 Erewhile must perish in the wrecks of time;
 Should round thy brow innocuous lightnings shoot,
 And to fierce whirlwinds shake thy steadfast root;
 Yet shalt Thou fall !—thy leafy tresses fade,
 And those bare shatter'd antlers strew the glade;

Arm

Arm after arm shall leave the mouldering bust,
And thy firm fibres crumble into dust!—

But MUNDY'S verse shall consecrate thy name,
And rising forests envy SWILCAR'S fame;
Green shall thy gems expand, thy branches play,
And bloom for ever in the immortal lay.

S E C T. XIX.

PRODUCTION OF FLOWERS.

- I. Flowers from seeds. 1. Double flowers from seeds. Hereditary diseases in plants. Full flowers have no stamina. Three kinds of double columbine. Vegetable monsters analogous to animal mules. The stamen, pistil, and calyx, are the most unchangeable parts. Double flowers distinguished by the calyx, are much more durable than single ones. Double poppies yield more opium. Annual insects. 2. The colours of single flowers from seed how varied. Variegation of foliage. Vegetable juices are hyper-oxygenated. This fluid oxygen is converted into gas by the sun's light; which therefore colours living vegetables, and bleaches dead ones.
- II. 1. Flowers from buds. Double ones how caused. Surround the bud with water. Oil, and conserve of roses. Their double flowers. Acquired habits. 2. How to vary the colour of single shrub-flowers, by anther-dust, by inoculation. Trees how variegated by ingraftment, or made into evergreens. 3. How to increase the number of flowers. III. 1. Flowers from roots. Bulb-rooted flowers. To cause their duplicature, break off the flower, raise them out of the ground. 2. Single bulb-rooted flowers. To increase them in size or number, take away offsets, crowd their roots. Propagation by offsets. By seeds. How broken into colours. Plant them in different soils. Tulips break into colours from age. 3. Perennial branching roots. Duplicature of their flowers, propagated by offsets, by seeds. Their single flowers. How broken into colours. By seeds, by transplanting. IV. Esculent and medicinal flowers. Vegetable mucilage coagulated by boiling in water, in steam. They lose their green colour in steam, Why? Artichoke-stalks. 2. Cultivation of brocoli. Knobs on its roots. 3. Hop. Camomile. Their duplicature. V. Flowers used in the arts. For dying, ornotto. For spinning, cotton, cotton-rush, cat's-tail. VI. Nutritious parts of vegetables. 1. Mushrooms. Gluten of Wheat. Oils. 2. Sugar. Mucilage. Oil. 3. Starch. Meal. 4. Albumum. Barks. Roots of fern
and

and of bryony. 5. Immature flowers. Honey. Leaf-stalks. Leaves. Reservoirs of nutriment. VII. Happiness of organized nature. 1. Seeds and eggs have not sensitive life. Milk gives two-fold pleasure. Dull animals and diseased vegetables perish, and give life to more sensible ones. Old age unknown before society. Misery is not immortal. 2. Animal absorption and secretion is attended with agreeable sensation. Renders matter more solid. The same in vegetables. 3. Strata of limestone formed from animal shells. Those of coal, clay, sand, from vegetable secretions, gave pleasure at the time of their production; and are monuments of past felicity, and of the benevolence of the Deity. VIII. Cultivation of brocoli, a poem.

THE beautiful colours of the petals of flowers with their polished surfaces are scarcely rivalled by those of shells, of feathers, or of precious stones. Many of these transient beauties, which give such brilliancy to our gardens, delight at the same time the sense of smell with their odours; yet have they not been extensively used as articles either of diet, medicine, or the arts. For the purpose of cultivation they may be divided into those immediately derived from seeds, those from buds, and those from roots; to which may be added the esculent and medicinal ones, and those used in the arts.

I. *Flowers from Seeds.*

1. The eye of the florist is frequently delighted with double flowers, which shew a greater blaze of colour in a small space, and continue some weeks longer in blow than single ones; and, though they are properly called vegetable monsters by the botanists, may give information to the philosopher in respect to the sexual generation of vegetables. The method therefore of producing double flowers from seeds is a matter of importance, as well as the art of giving to both these and the single flowers their most healthy expansion, and the greatest brilliancy and variety of their colours.

Though those multiplied flowers, which are said to be full, possess no stamens, or pistils, and consequently can produce no seeds; yet are they frequently raised immediately from seeds; for those flowers, which are cultivated with more manure, moisture, and warmth, than is natural, become more vigorous and larger, and at the same time are liable to shew a tendency to become double, by having one or two supernumerary petals in each flower, as the stock July-flower, cheiranthus, and anemone. And what is truly curious, this tendency to duplicature is communicated to the seeds of those individual blossoms; inasmuch that florists are directed to tie a thread round such flowers, which have a supernumerary petal, to mark them, and to collect their seeds separately; which are said uniformly to produce double or full flowers, if cultivated as above with rather more manure, moisture, and warmth, than those plants have naturally been accustomed to.

The analogy of this circumstance with the hereditary diseases of animals is truly wonderful; as the children of those parents, who have acquired the gout or dropsy by intemperance in the use of fermented or spirituous potations, become afflicted with those diseases, as I have frequently observed, in a much greater degree by the same quantity of intemperance, which originally produced them in their parents; or they acquire the same quantity of those diseases by a less degree of intemperance, than occasions them in others, whose parents have not used fermented or spirituous liquors to excess.

The luxuriance of flowers, which is believed to arise from their cultivation in more nutritive soils with greater moisture and warmth, consists in the increase of some parts of the flower, and the consequent exclusion of others; and is distinguished by Linnæus into the multiplication and plenitude of flowers, and into proliferous ones. Multiplied flowers consist of double, triple, or quadruple corols; but full flowers are so multiplied as to exclude the stamina; while in proliferous ones other flowers arise from within the principal

principal flower, and frequently from its center. Philos. Botan. p. 80.

It is supposed that the stamina of some double flowers are converted into petals; but on examination, I suspect that the number of petals is increased, and the stamina prevented from growing by being compressed by them in their nascent state; as in many of them, I believe, the rudiments of some stamina may be seen, as in *ranunculus*. So when a new flower rises in the center of the old one, it is supposed, that the pistillum is converted into the stem of a new flower, as in *proliferous daisy*, *bellis prolifera*; but I suspect, that the pistillum is prevented from rising by the immoderate growth of the new flower-stem; as in some of them, I am told, the rudiment of the pistillum may be perceived.

Thus monopetalous flowers are doubled or multiplied by the increased divisions of the limb, as observed by Linnæus, Philos. Botan. p. 83, who adds, that the metamorphosis of English soapwort is very singular, as its five petals are transformed into one petal, and that in *opulus flore globofo* the central florets become similar to those of the circumference, acquiring wheeled corols, and being barren: in these cases the stamens cannot be changed into corols, as the number of corols is not increased. Afterwards, in p. 84, the same illustrious author observes, that in double *lychnis* the rudiment of the common pistil is present.

The luxuriance of flowers therefore consists in the multiplication of the corols or nectaries, which last are properly an appendage to the former; and the prevention of the growth of the male and female organs is the consequence. Thus the flower of *aquilegia*, *columbine*, has three kinds of plenitude: 1. the petals become multiplied, and the nectaries excluded; 2. the nectaries are multiplied, and the petals excluded; 3. the nectaries are multiplied, the petals remaining. So that there are five petals, and between each of these three nectaries, which exist within each other.

A curious

A curious analogy here also exists between these vegetable monsters and those of the animal world ; as a duplicature of limbs frequently attends the latter, as chickens and turkeys with four legs and four wings, and calves with two heads. And in mules the parts subservient to generation become deficient, whence they cannot propagate their species ; exactly as in these full flowers, which can thence produce no seed. And in respect to botanic systems, it may be observed from these vegetables of luxuriant growths, that the stamens and pistils are less liable to change than the corols and nectaries, and are therefore more proper parts for the classification of plants ; on which idea Linnæus has constructed his unrivalled system. And lastly that the calyx, or perianth, is the next most unchangeable part of the flower, as this is seldom doubled or multiplied ; and that hence by inspecting the calyx the genera of many double flowers may be detected ; thus the double ranunculus possesses a calyx, but the double anemone is without one, like the single ones of those genera.

The greater duration of double flowers than single ones is so remarkable in some poppies, that their single flowers lose the corolla in a few hours, while in the double ones it continues several days : this circumstance is well worthy the attention of those, who cultivate poppies for the purpose of wounding the head, which incloses the seeds, for the opium, which thus exsudes. As poppies with double flowers may probably be capable of yielding opium, before they shed their flowers, and as long as other poppies, after they shed them, Dr. Smith ascribes this event to the organs of reproduction being obliterated, and the consequent want of impregnation ; by the great stimulus of which he thinks the vegetable irritability may be sooner exhausted in single flowers : and adds, “ that on the same account many plants resist a greater degree of cold for several winters before flowering ; but after that event they perish at the first approach of cold, and can by no art be preserved so as to survive the winter.”

And repeats an observation from Linnæus, that the pistilla of the female hemp, *cannabis*, continued much longer to exist when not exposed to the male pollen, than those pistilla on which the pollen had been effused. *Tracts on Nat. Hist.* p. 177.

It may be observed, that many insects may be called annual ones as well as many vegetables, and die, as soon as they have provided the eggs or seeds for the reproduction of their species, as the silkworm, and, I suppose, all the kinds of moths and butterflies; many of which take no food at all, after they have acquired their organs of generation and their amatorial passion, and yet appear fat and active; and others live only upon honey, and seem to die as soon as that passion is gratified, probably from having no further pleasureable stimulus to excite the animal power into activity, rather than from its total exhaustion; because other animals, whose existence is not naturally so short, are not injured or destroyed by the moderate use of the powers of reproduction; and that power leaves them long before their death. An experiment to shew, whether the moths of silkworms would live longer if deprived of their paramours, might be worth the attention of naturalists; and also, whether the butterflies of our climate might not be preserved during the winter, if fed with honey like bees, and kept from excessive cold. I directed some honey to be offered to the silkworm-butterflies, which they would not attend to, though they may probably seek for it in their native climates.

2. Varieties in the colours of single flowers raised from seeds may probably be generally acquired by sowing near together those of the same species, which already possess different colours; so that during the dispersion of their anther-dust by the wind, or otherwise, they may intermix and adulterate each other. Or this may be more certainly effected by bending the flowers of one colour, and shaking the anther-dust over those of another colour. In this manner, I suppose,

suppose, it happens, that the beds of *centaurea cyanus* become of such various and beautiful shades of blues, purples, and whites.

Another method of giving variety of colours to seedling flowers consists in sowing them on natural soils, or on factitious composts, which differ much from each other in respect to vegetable nutriment, and perhaps in respect to their colour, as some animals change their natural colours when in different situations of soil. As frogs much resemble the colour of the soil on which they live, and our domesticated horses, dogs, cats, rabbits, pigeons, and poultry, change their colours into endless varieties, owing to the difference of their nutriment or situation. But observations and experiments are wanting on this subject in respect to the colours of seedling flowers, as well as in respect to the variegation of the leaves of shrubs and trees; which last originates probably from soil or situation, and may be propagated by ingrafting.

As the origin of double flowers is believed to result from the luxuriant growth of the plant, owing to too much nourishment, moisture, and warmth, so the origin of new colours in flowers, and of variegated foliage, is thought to occur from the innutrition of the soil, on which they grow, compared to that which they have naturally been accustomed to, or from defect of moisture and of heat; which is countenanced by the dwarfish size of such plants in general, and especially by the lessened stature of tulips, when their petals break into variety of colours.

The proximate cause of the change of colours in flowers or foliage must be sought from the modern acquisitions of aerial chemistry. The presence of oxygen gas deprives dead vegetable fibres, as cotton-wool and the threads of flax, of their colour; that is, it bleaches them; which is probably owing to its uniting with the colouring matter and forming a new acid, which is transparent. Thus the hyper-oxygenated muriatic acid almost instantaneously deprives cotton and linen of their colour; and the sun's light on moistened
linen

linen spread upon the ground seems to decompose the water, and the oxygen thus detached whitens the linen. The etiolation or blanching of living vegetables on the contrary seems to originate from the want of the sun's light to convert into gas the fluid oxygen; which, by dissolving their colouring matter, and forming new and perhaps tasteless acids, deprives them of colour. Hence the water, which vegetables perspire in the sunshine, becomes hyper-oxygenated, which has much puzzled philosophers to account for; and the oxygen rises from it without decomposing it; which last circumstance is evinced by the total absence of the smell of hydrogen, which so powerfully affects our nostrils, when a spoonful of water is thrown on burning coals.

Now as plants, which grow less vigorously from defect of nutriment, moisture, air, or warmth, may acquire or possess less oxygen to dissolve their colouring matter, their structure may approach towards that of dead vegetables; and hence they may become bleached instead of coloured by the influence of the sun's light, especially in those parts where their vital functions are performed with less vigour; so an etiolated vegetable, as a blanched plant of celery, apium graveolens, becomes green in a few days, when exposed to the light and air; and white again, if deprived of life, and exposed to the sunshine and dews.

The immediate cause of the various colours of some flowers, as of poppies, might be a subject of curious investigation. I once supposed, that the thinness of the pellicle of some flowers might occasion them to reflect different colours, as is seen on dropping a drop of oil from a bridge on the water below on a bright day. But colours thus produced vary with the situation of the observer, in respect to the obliquity or angle of reflection, in which they are seen; and are thence variable with every motion of them, as those colours seen on soap-bubbles, and on mother-pearl, and on the Labradore-stone, and on some silks. For those colours depend on the thinness of the

reflecting surface, which when seen more obliquely become thicker; and then reflects those colours, which passed through thinner plates; in the same manner as the red light of the setting sun is reflected from glass windows, seen very obliquely by the observer.

The colours of flowers therefore, as they are not variable by the obliquity, with which they are seen, like those of mother-pearl card-fish, do not depend on the thinness of their pellicle; but, I suppose, to the greater facility that some parts of them possess in parting with their oxygen, when exposed to the sun's light, than other parts of them; for all flowers are more or less etiolated, before they first open. In the silk manufactory a variable colour is produced by making the warp of one colour and the woof of another; perhaps the variable colour of a peacock's tail may be owing to a mixture of different coloured down placed in lines near each other.

II. *Flowers from Buds.*

I. The flowers arising from the buds of shrubs or trees are liable to become double or full by the multiplication of their petals, as those of roses, cherries, hawthorn, peach, rosa, prunus, cerasus, crategus oxyacantha, amygdalus persica. Which tendency to duplicature, as in the flowers of annual plants, is probably owing to the too vigorous growth of the bud from a too nutritious soil, or the combination of abundant moisture and warmth, and would probably be forwarded by surrounding the bud itself frequently with water; as is so beautifully seen in those plants, which have a cup round their joints to preserve for a time the rain, which falls upon them, as round the joints of dypfacus, teasel, silphium, tillandsia, and nepenthes.

It is remarkable, that though the duplicature of many flowers is believed to have been owing to the more nutritious soil, in which they

they have been cultivated, yet that, when transplanted into less fertile soils, or ingrafted on less luxuriant trees, they still retain their tendency to duplicature; which can only be ascribed to the continuance of an acquired habit, or to the succession of hereditary diseases, so frequently observed in the animal system.

This duplicature of flowers from buds is generally propagated by ingrafting the scions of such, as bear multiplied petals, on similar plants, which bear single flowers; and may be of service not only for beauty, but for the purpose of increase in those plants, the petals of whose flowers are consumed for any purpose, as the leaves of roses. A gentleman at Nottingham annually distils a profitable quantity of essential oil of roses, by collecting all of them he can purchase in the neighbourhood during the season; and this by the usual process, which is not difficult though tedious. And a surgeon at Stafford has introduced an agreeable and profitable kind of agriculture, by planting half an acre of ground with red roses, and converting the flowers into conserve with sugar, or by simply drying them for the London market.

2. It is probable, that numerous varieties of colour in the single flowers of shrubs, as well as those of annual plants, might be obtained by shaking the anther-dust of one variety over the stigma of another, where any difference of colour already exists in the same species. And perhaps some changes of colour of the flowers might be produced by inoculating the buds of a shrub, whose flowers are of one colour, into the branches of another variety of the same species or genus; as the variegation of the foliage of plants is said to have been produced in this manner, according to the assertions of Mr. Bradley and Mr. Laurence, who budded a spotted passion-flower and a striped jasmine on those, which were not variegated, and produced a similar variegation of them, as related in Sect. V. 1. This has been ascribed to the absorption of some infectious matter from the inoculated bud, which propagated a similar disease to the whole tree; and

has thence been used as an argument in favour of a vegetable circulation of juices.

A similar fact is also asserted by Mr. Milne. He says, that “an evergreen tree ingrafted on a deciduous one determines the latter to retain its leaves; this observation is confirmed by repeated experiments, particularly by grafting the laurel, *laurocerasus*, an evergreen, on the common cherry, *cerasus*; or the ilex, an evergreen oak, on the common oak.” *Botanical Dict. Art. Defoliation*. All these seem to want further experiments to authenticate the facts so delivered on the authority of ingenious men.

3. To increase the number of the flowers of shrubs, all those arts are applicable, which are described in Sect. XV. 2. for the production of fruit on wall trees; which, when the tree is of a proper age, consist, 1. in bending down the viviparous branches to the horizon; which renders them oviparous; 2. by twisting a wire, or tying a cord round the viviparous branches; 3. by wounding or cutting away a narrow cylinder of the bark; 4. by transplanting or cutting off some of the roots; 5. by cutting away the central or viviparous branches; 6. by ingrafting.

III. *Flowers from Roots.*

1. Many bulb-rooted flowers are deservedly in great estimation by florists, as the tulip, hyacinth, lily, colchicum, crocus, fritillary, &c. and of those many are liable to become double, which adds in general so much to their splendour and to their duration, as narcissus, hyacinth, colchicum, tulip.

The immediate cause of duplicature or multiplication of the petals of these flowers is probably similar to that of those above mentioned, and originates from their luxuriant growth, owing to the fertility

fertility of the soil, and the abundance of moisture and of warmth in combination.

Other circumstances, which may add to their luxuriant growth, may also contribute to their duplicature; such as by breaking off the flower as soon as it begins to fade; and thus, by preventing the nutritious vegetable juices from being expended in the growth of the seeds, more of it may be derived to the principal succeeding bulb.

Thus it is asserted, that the preventing some annual plants from flowering lengthens their lives, which it may effect by occasioning them to produce new root-scions, and thus to become perennial vegetables. The very ingenious Mr. Bogle, in the papers of the Bath Society, believes that wheat, oats, and barley, may be made perennials, if they are eaten down by cattle or sheep, or cut by the scythe or sickle, so as to prevent them from producing ears.

As tulip-bulbs raised from seed produce a larger bulb the succeeding year, and again a larger with a different leaf on the third year, and so on till the fifth or sixth, the bulbs thus annually improving till they flower; and even after they flower they are believed to continue to improve for some years, till the colour of the petals become striped: I suspect that the art of procuring a great duplicature of the petals of these flowers consists in breaking off the flower-stem on the fifth, sixth, and seventh years, from the sowing of the seed; that is, for a year, or two, or three, after the flower-stem first appears, as noted in Sect. VIII. 1. 3. And that the tendency to duplicature will continue in the succeeding bulbs by the acquired habit, as in the hereditary diseases of animals.

And secondly, these flower-roots become more luxuriant by raising them out of the ground, as soon as the leaves wither, which are the parents of the new bulbs; and then by taking away the smaller or collateral new bulbs from the principal one, which might otherwise incommode its growth by their vicinity, and consequent compression,

sion, both these methods are of equal use to enlarge and render more vigorous the single flowers of bulb-roots, as well as to increase their tendency to duplicature.

2. The single flowers of some of these plants may be probably not only enlarged, but so strengthened as to ripen their seeds in this climate, by nicely laying bare the root, and taking from it the new progeny; whether a single new bulb, as in orchis mascula, or the numerous ones of hyacinth, tulip, or lily of the valley; as by these means the vegetable nutriment is not expended on the new bulbs, and probably more of it may thence be derived to the flower. See Sect. XVII. 1. 3.

Another method of increasing the bulb-rooted flowers in size or number consists in crowding their roots in garden-pots, or by not annually transplanting them; and thus by preventing their offsets from being formed, or by decreasing the number or vigour of them; thus lily of valley, and jonquil, seldom afford large or numerous flowers, till they have remained three or four years in the same situation; but must nevertheless be then occasionally in part transplanted, lest the roots should die from being so crowded as not to form each of them one annual new bulb, which is their mode of reproduction.

The usual method of propagating bulbous roots has been by the smaller offsets, which are formed annually round the principal or central new bulb, as in tulips; which central new bulb has commonly been mistaken for the old root; by this mode of propagation the similarity of the new progeny to the parent is nicely preserved; and on that account some of these new roots of tulips and hyacinths have been sold at extravagant prices. For the circumstance of this mode of reproduction see Sect. IX. 3. 2.

But in respect to producing variety of colour in the single flowers of bulbous roots, the most effectual method, I suppose, must be by sowing their seeds, and waiting a few years, till their successive bulbs

at

at length produce flowers, as described in Sect. XVII. 1. 2. and particularly if the anther-dust of one variety in respect to colour be shed on the stigma of another variety.

Another method of producing a change or variety of colours in bulb-rooted flowers may be by planting them every year, till they flower, on very nutritious soil, with an abundant combination of moisture and of heat, as these two elements should exist together to effect the most luxuriant growth of vegetables. And after they have flowered, or on the year in which they are expected to flower, they should be transplanted on a less nutritive soil, with less heat and moisture. Or probably this less quantity of nutriment, heat, and moisture, might be used at the commencement of their growth, or even at sowing their seed, with similar effect of sooner breaking into variety of colours.

The beauty of the double yellow tulip, and its greater longevity, much recommend it to common eyes ; but the endless variety in the colours of single tulips has long and deservedly been the admiration of florists. The curious event of their breaking into various colours from an uniform purple, a year or two after their first flowering, and at the same time of their losing nearly one third of the height of their stems, seems to indicate, that this effect results not from the debility of age, but from the acquisition of hereditary diseases, as these new colours, into which they break, afterwards remain for uncounted generations, and may in this respect be compared to the canker in apple-trees, mentioned in Sect. XIV. 1. 3.

This change of colour from darker to lighter in tulips may probably be accelerated or increased by keeping the roots long out of the ground in dry or warm apartments, so as to harden their fibres, and diminish the diameters of their secreting vessels, and thereby hindering their absorption of colouring molecules, similar to grey hairs produced on animals by age or external injury of the part. This would seem to obtain in tulips, as when they break into colours,
I. they

they lose one third of their size, and consequently the diameters of their secretory and of their absorbent vessels must be much diminished.

New kinds of varieties in the situations or production of white parts of the petals of flowers might be caused, I suspect, by compressing some parts of them before the flower opens, by tying fine threads round the calyx, which incloses them; as many darker coloured cats and dogs have all those parts lighter or quite white, which have been compressed together, as they lay in their fetus state in the uterus; an instance of which exists in a black male cat, which now lies upon the hearth, and an instance of a black terrier bitch is described in *Zoonomia*, Vol. II. Class I. 2. 2. 11. This may be worth the attention of florists and flower-sellers; and it is probable, that the white streaks in dark flowers may have been thus produced by their greater compression in the calyx, before the flower opens.

3. The causes of duplicature in perennial flowers with branching roots, as *ranunculus*, *caltha*, *hepatica*, *anemone*, *cheiranthus*, *dianthus*, *silene*, *wallflower*, *carnation*, *catchfly*, are probably such as afford a general luxuriancy of growth to those vegetables, and may be certainly propagated by offsets from those roots, or by laying their branches in the ground, so as to exactly resemble their parents. Many of these double flowers may also be procured by collecting the seeds from such single flowers of the same species, as possess a super-numerary petal; which, if sowed on fertile ground, will present us with double or multiplied flowers, as the *anemone* and *july-flower* mentioned in No. I. 1. of this Section.

The effect of breaking the single ones into varieties of colour, which, in *anemones* and *poppies* as well as in *tulips*, are uncommonly beautiful, is probably owing to the less fertility of the soil, or less supply of heat and moisture, where they have happened to reside, and that more effectually if they were removed from more favourable situations.

The

The varieties of the single flowers also of those roots may be propagated unchanged, as well as the double ones, by dividing the roots or transplanting the offsets, or by laying their branches in the ground, as of pinks and carnations. Other varieties may be procured by collecting seeds and sowing them in dissimilar soils and situations; and such flowers as are of approved beauty, may probably be occasionally strengthened and enlarged by depriving them in part of their offsets early in the season; or may be broken into colours by keeping the roots some weeks or months out of the ground in the autumn in dry or warm apartments.

The colours of flowers of this kind, I believe, are frequently changed by situation; in my garden some roots of comfrey, *symphytum*, with purple flowers had long existed on a moistish border; and last year other roots, I suppose from the seeds of the former, grew in a dryer situation, and bore white flowers. And Mr. Bradley asserts, in his *Philos. Account of Nature*, p. 71, that some roots of purple *hepatica*, which were removed from Tothill-fields to Henley on the Thames, became white; and became purple again, when they were returned to their native situation.

IV. *Esculent and Medicinal Flowers.*

1. The esculent flowers most in use at our tables have their mucilage in some degree coagulated by boiling them in water or in steam, and are consumed before their maturity, as those of artichoke, *cinara scolymus*; of mercury, *mercurialis*; of sea-cale, *crambe maritima*; and of brocoli and cauliflower, *brassica oleracea italica* and *botrytis*. The flowers of the nasturtion, *tropeolum majus*, possess an agreeable acrimony, and are eaten raw, shred with the fresh leaves of lettuce, young mustard plants, or red cabbage. Other flowers are used for domestic or medicinal purposes, as those

of hops, *humulus lupulus*, camomile, *anthemis nobilis*, roses, cardamine, violets.

The three foremost of these, the artichoke, and mercury, and sea-cale, are perennial plants; and, as they put forth numerous root-scions or offsets, may have their principal stem much invigorated, and will consequently produce larger flowers, by taking away many of these offsets, so as to leave but two or three on a root. And as the ripening of the seed is no object, a greater abundance of moisture, than these plants have been naturally accustomed to, with proportional increase of warmth in respect to situation, will forward their growth, and increase their size.

A great part of the nutritious mucilage in the artichoke is placed in the upper part of the stem, as well as in the pericarpium of the flower, which should therefore be boiled along with it for the purpose of coagulation; and might then probably be managed so as to resemble fagoe, if granulated by passing it through sieves.

The art of boiling vegetables of all kinds in steam instead of in water, might probably be managed to advantage, as a greater degree of heat might be thus given them, by contriving to increase the heat of the steam after it has left the water; and thus the vegetable mucilage in roots and seeds, as in potatoes and flour-puddings, as well as in their leaves, stems, and flower-cups, might be rendered probably more nutritive, and perhaps more palatable.

But many of the leaves of vegetables, as the summits of cabbage-sprouts, lose their green colour by being boiled in steam, and look like blanched vegetables. This etiolation of some vegetables by steam is probably owing to its dissolving their colouring matter, which may then become decomposed; and may render them less agreeable to those who choose by the eye rather than by the palate; which green colour is however heightened by boiling them in some hard waters which contain dissolved lime or sea-salt, or by a slight admixture of common salt with soft water. An effect which

is owing to the evaporation of a part of the marine acid, and to the remaining alkali, which was the basis of it, when applied to bluish vegetables converting them into green, as in the common experiment of adding salt of tartar to syrup of violets; or, according to the custom of some cooks, who add a little potash, or fixed vegetable alkali, to the water, in which young peas are boiled to make them green, and afterwards a very little sugar to sweeten them.

The same effect of making vegetables green, when boiled in other kinds of hard waters, is probably produced by the lime, which abounds in them; and which like the vegetable alkali when the aerial acid, which was united with it evaporates, is said to convert bluish vegetable colours into green ones.

The nutritious mucilage resides likewise in the young stems of mercury, which should therefore be eaten before the flower begins to open. The stalks and immature flowers of sea-cale are similar to good brocoli, if eaten young; though many gardeners prefer the blanching them, which supplies an early and agreeable repast, described in Sect. XIV. 3. 3. Asparagus does not perhaps properly belong to this section, as the stem is eaten, before the flower becomes visible.

2. The cultivation of brocoli and cauliflower must be very similar, except as to the seasons of the year, as they are varieties of the same species of plant of the cabbage family. The following directions for the cultivation of brocoli were sent me by Edward Tighe, Esq. an ingenious gentleman of Ireland, along with an elegant Latin poem on the same subject, a free translation of which is placed at the end of this section.

“ Brocoli may be so managed as to supply the table with a delicious and salutary vegetable during the months of November, December, January, February, March, April, and May.

1. Procure prime seed from Rome or Naples both for early and late sowing.
2. Sow at the cessation of the vernal snows, and repeat it once a month till the end of May, or longer.
3. When three leaves appear, transplant them; and when six leaves appear, transplant them again. Afterwards in June, July, and August, transplant them two or three feet asunder, to remain.
4. During September and October the ground must be loosened, and repeatedly cleared from weeds and stones; and the plants earthed up to preserve their roots from the frost, and to prevent their being injured by the equinoctial winds.
5. Water them occasionally with water impregnated with dung.
6. Sow and plant them far from hedges, trees, and walls.

The head is generally completed in five or six days from its first appearance, and should not remain much longer; the stalk should be boiled with the flower, and peeled in the kitchen, before it is brought to the table."

Some kinds of Italian brocoli are said to produce some knobs or bulbs at their roots, which are supposed to be for the purpose of raising other stems; if this last circumstance be ascertained, they should be broken off, when the principal stem is transplanted; like the new root of orchis to enlarge the flower, mentioned in Section XV. 2. 4. But they may be simply a reservoir of nutriment for the principal stem, as in carrots and turnips; in that case they should certainly remain, and be transplanted along with the stem.

3. In respect to the flowers of hop, *humulus lupulus*; and chamomile, *anthemis nobilis*; as well as those of roses, violets, cardamine, and the nasturtion above mentioned; as their petals only are required, it would add much to their quality, if they could be cultivated in their double or multiplied state, as is generally indeed practised

practised in respect to roses and chamomile ; many acres of the latter of which are cultivated near Chesterfield in Derbyshire, and are sold, I am informed, to mix with hops, when those crops are deficient, as well as for the purposes of medicine. What might be the effect of endeavouring to introduce a duplicature or multiplication of the flowers of artichoke, sea-cale, cauliflower, and brocoli, has not, I believe, been experienced.

v. *Flowers used in the Arts.*

1. The beautiful membrane, which covers the seeds of euonymus, or spindle-tree, and of the bixa of South America, is said to be manufactured into the anotta, or arnotta, used in colouring cheese ; but I am told that madder, made from the root of *rubia tinctoria*, is sold frequently in its stead, and may be readily grown by farmers in their own gardens. Few flowers are used in the art of dying, their colours are so fugitive, as they readily bleach when exposed to the light, and cannot be kept long even in the herbariums of botanists without losing their colours ; which is believed to be owing to the oxygen of the atmosphere being separated from the aerial water by the sun's light, and converted into a gas combined only with heat or light, and in that state more readily uniting with the colouring matter of flowers, and producing a new acid, which is transparent, colourless, or white, or is dissolved and washed away by the dews or rains.

The blue colour of the flowers of violets has been extracted by water, and preserved by the addition of sugar converting it into syrup for the purposes of medicine in part, but chiefly for those of chemistry, to shew the change of vegetable blues into greens by an admixture of fixed alkali, as salt of tartar or potash ; and into red

by the admixture of an acid, as those of sulphur, nitre, or marine salt.

2. Another very important flower, which is suffered to grow to maturity for the purpose of using the fine fibres which wing or envelope its seeds, is that of the cotton plant, *gossypium*; which, as it requires so much less preparation than the fibres of the stems of flax and of hemp or nettles, is likely to become the principal clothing of mankind; and especially since the art of spinning it was brought to such wonderful perfection by the genius of Sir Richard Arkwright, who discovered that two sets of rollers moving with different velocities would draw out the fibres of cotton into a fine thread more accurately than could be done by the human hand, as well as more expeditiously, along with much other very ingenious machinery.

There are two bog or water plants in our morasses, which produce much vegetable fibres attached to their seeds, one of these is the typha, or cat's-tail; and the other *eriphorum*, or cotton-rush. The fibres of the former are short and coarse, but might serve perhaps to stuff cushions, or even coarse beds; those of the latter are longer, and perhaps fine enough to spin. And as both these only grow on bogs or in water, where we at present cultivate no useful vegetables, one, or both of them, might possibly be worthy the attention of those, who possess aquatic or marshy situations. The cultivation of the cotton plant belongs to warmer climates, and may probably require abundant water for its vigorous growth, as well as the typha and *eriphorum* of this country.

VI. *Nutritious parts of Vegetables.*

1. Having treated of the cultivation of fruits, seeds, roots, barks, leaves, woods, and flowers, an important question presents itself; which

which of them may supply the most nutrition to mankind, or to other animals?

It may be answered first, that those vegetables, or parts of vegetables, which approach nearest to the nature of animal bodies, are most likely to supply them with the most nutriment; as the esculent mushrooms, and the gluten of wheat, and the oils of seeds and kernels. The former class of plants seems to connect the animal and vegetable kingdoms of nature, as spoken of in Sect. XVII. 2. 5. and though many of them possess an acrid, and some of them an intoxicating quality, it is probable that the former might be destroyed, and the latter diminished, by the heat employed in cookery. This should nevertheless be attempted with due caution; since, though one kind of vegetable acrimony, as that of water-creffes and of cabbages, is much diminished or destroyed by a boiling heat, yet that of the leaves of *arum maculatum*, and of *arum arifarum*, I found by experiment, was not decreased by boiling. And a few grains of the powder of *lycoperdon*, puff-ball, have lately been recommended in epileptic fits, and may thence possibly possess a powerful narcotic quality. The gluten of wheat is supposed to approach towards the coagulable lymph of animal bodies, as referred to in Sect. XVI. 7. 1. and was once, I believe, advertised as an alimentary powder, and recommended as a nourishment of the most portable kind for the sustenance of marching armies. And lastly the oils of vegetables approach much to a similitude with those of animal bodies.

2. Secondly, it may be answered, that since the chyle of all red-blooded animals is believed to be nearly similar, and to consist principally of sugar, mucilage, and oil; the last of which ingredients renders it white by its insolubility in water, and thence distinguishes it from the vegetable chyle or sap-juice of trees, which is transparent, and is believed to consist principally of sugar and mucilage without oil; those parts of vegetables which contain the greatest quantity of

these ingredients which compose animal chyle, or are convertible into them by the power of digestion, may be supposed to contain the most nutriment for red-blooded animals.

To this may be added, that the nutritive quality of sugar is incontestably evinced from the known fact, that the slaves in the sugar islands become in better condition during the sugar season, though they are compelled to labour harder. The nutritive quality of simple mucilage was shewn in a remarkable instance on record; where a caravan by some misfortune had consumed or lost all their other provisions, and lived many weeks on the gum arabic alone, which constituted their principal merchandise. The nutritive quality of oil is observable in the process of feeding cattle with oil-cake, and in the habits of the natives of the northern latitudes, who use the oil of fish for both meat and drink, and derive from it their principal nourishment.

Sugar is known to be the same, from whatever vegetable it is extracted, whether from the fruit of the vine or apple-tree, from the joints of the sugar-cane, from the sap-vessels of the maple, from the alburnum of the manna ash, from the seeds of germinated barley and rice, from the roots of beets, carrots, and potatoes, or, lastly, from the nectaries of flowers. The expressed oils of vegetables are also believed not much to differ from each other in respect to the nutriment they contain, though some of them may approach nearer to the nature of animal fat; as the painters distinguish them by their greater aptitude to dry, when mixed with their colours and exposed to the air. But the word mucilage has been used for starch, which will not dissolve in cold water, as well as for gum arabic, and other mucilages properly so called, which will dissolve in cold water, and even for the gluten of wheat, which will not dissolve in either hot or cold water. We may therefore conclude, that those parts of vegetables, which contain the most of these materials, are the most nutritive,

nutritive, if they do not contain along with them some noxious materials united with their salutary ones, and which cannot be readily separated from them.

3. Though the parts of vegetables, which possess much oil, sugar, or mucilage, may afford more expeditious nutrition, as they constitute the ingredients of the chyle of all red-blooded animals; yet there are other materials, which appear to be so readily convertible into sugar or into mucilage, as perhaps nearly to supply an equal quantity of nutriment. Thus by the process of germination, as when seeds of barley are converted into malt, and when roots pullulate in our store-rooms, as of onions or potatoes; the farina, consisting of meal or starch, is in part converted into sugar, and in part into mucilage; similar to this process of germination appears to be that of ripening, by which the austere juices of fruits are transmuted into sweet ones; and also the culinary processes of baking or boiling, by which the austere juices of unripe pears are changed into sweet ones by the application of heat, as mentioned in Sect. VI. 5. But another more expeditious conversion of vegetable materials into sugar is by the digestion of animals, which may be truly termed a saccharine process; as appears in those, who labour under diabates, as by evaporating the urine of one of these patients, sixteen ounces of impure sugar were daily extracted for some time. Zoonomia, Vol. I. Sect. XXIX. 4.

Hence, though the oily kernels of nuts, walnuts, almonds, and the oily seeds of flax, hemp, rape, may contain most expeditious nutriment; and next to these the saccharine fruits of figs, dates, raisins, and the sweet roots of beet, mungel-worsal, ground artichoke, helianthus tuberosus, parsnip, carrot, may contain expeditious nutriment. Yet the more farinaceous seeds, as of wheat, peas, rice, barley, oats, and buck-wheat, polygonum fagopyrum, and the roots of potatoes, which contain starch, and flour, and mucilage, which are convertible into sugar in the stomachs of animals, and are pro-

bably by that digestive process, and their previous mastication in the mouth, mingled with more animal coagulable lymph, as the saliva, gastric, and pancreatic juices, and may thus supply a more animalized nutriment than the former; and may on that account contribute more to strengthen the system. Of these seeds and roots it appears probable, that those, which contain the most starch or gluten, as wheat, afford the most nourishment, as they are believed to make the best bread.

4. The alburnum, or sap-wood, of most trees in the winter months probably contains much nutritious matter; whence it is soon destroyed by fermentation or putrefaction when deprived of life; and by insects, when it is deprived of its protecting bark. This nutritious matter might be obtained by grating, or rasping, or pounding it, and boiling the powder or saw-dust thus procured. The bark of all those vegetables, which are armed with thorns or prickles, is believed to contain much nutritious matter, which their armour was designed to protect; as the inner barks of elm, holly, gooseberry, whin or gorse, contain much nutritive mucilage; thus the deer in Needwood Forest greedily peel the bark from the branches of holly, which are cut from the summits of those trees, where they have no prickles, as mentioned in Botanic Garden, Vol. II. note on Ilex. And horses are said to be well nourished by gorse, if the prickles are previously destroyed by rolling a stone over it, as the tanners bruise their oak-bark; and some horses are said to be so fond of it, and so wise, as to bruise young gorse-bushes with their feet, and then to eat them.

Fern roots are said to be eaten by the natives of New Holland, and in other countries in times of scarcity; but as their farinaceous or mucilaginous matter is included in ligneous fibres too hard for mastication, the method of cooking it is said to consist in boiling the root, and then extracting the fibres by hammering it to pieces. The root of white bryony, which grows to a great size in our hedge-bottoms,

toms, is said, by M. Permentier, to possess a quantity of starch, which was capable of being washed from the acrid mucilage by grating it into cold water, and of being manufactured into an agreeable and salutary bread; like the bread made from the cassava, which is said to undergo a similar process, by expressing some of the acrimonious mucilage previous to the application of the heat of cookery. Which however not only destroys the acrimony of many vegetables, as of water-creffes, cabbages, and the skins of potatoes, but is also believed to render some of them more nutritive by coagulating their mucilage, which was previously combined with too great a proportion of water.

5. It would appear therefore in general, that the seeds or kernels of vegetables afford the most nutriment; next to these their fruits and roots; and afterwards the alburnum or bark. Some of the flowers also in their early state before impregnation, as those of artichoke, cinara, and cauliflower, brassica, are nutritious from the mucilage, which they possess; and some seeds already impregnated, but still in their immature state, along with their husks or capsules, as those of kidney-bean, phaseolus, and of very young peas, afford a salutary nutriment. And lastly all flowers after the expansion of their corols secrete honey; which supplies food to innumerable insects, who plunder it, as well as to mankind. In the bases of many leaves another saccharine or mucilaginous juice is secreted, as at the joints of grafts, on the bulbs of onions, and at the lower parts of the leaves of cabbages, and around the stems of asparagus, mercury, and hop-buds, during the early state of their flowers; but the leaves themselves, like the lungs of animals, seem to possess less nutritious aliment than many other parts of their system.

VII. *The Happiness of Organic Life.*

All organized nature may be divided into stationary organizations, and locomotive organizations; the former of which are called vegetables, and the latter animals. All those parts of vegetables, which are most nutritious to animals, consist, as observed above, of aliment secreted from the vegetable blood, and laid up in reservoirs for the future sustenance of their embryo or infant progeny; which reservoirs are plundered by locomotive animals, and devoured along with the progeny, they were designed to support! add to this, that the stronger locomotive animals devour the weaker ones without mercy. Such is the condition of organic nature! whose first law might be expressed in the words, "Eat or be eaten!" and which would seem to be one great slaughter-house, one universal scene of rapacity and injustice!

1. Where shall we find a benevolent idea to console us amid so much apparent misery?—I hope the sympathizing reader will not think the following account of the happiness, which organized beings acquire from irritation only, impertinently inserted in this place; their happiness derived from imagination and volition may be treated of in some future work.

It may first be observed, that the seeds of plants and the eggs of animals, when they have left the pericarp or uterus, and have not yet commenced their new growth upon the soil, or beneath the wings of the mother, exist in a torpid state, not possessed of sensitive life; and cannot therefore at this time be supposed to suffer pain, when they are destroyed by other animals; though those animals obtain pleasure from the activity, into which their vascular systems are excited by the stimulus of the aliment thus supplied.

Secondly, that the young of lactescent animals both acquire and communicate pleasure to the enamoured mother, from whom they
receive

receive their nutriment, as mentioned in *Botanic Garden*, Vol. I. Canto I. l. 278, note ; which constitutes the most beautiful and most benevolent part of the great system of nature.

Thirdly, all animals, and, I suppose, vegetables, receive pleasure in the reproduction of their species ; and where seeds are dispersed on the soil, and the eggs of some animals and of many insects are buried beneath it, to be revived and hatched by the warmth of the sun ; there can be no pain in these cases inflicted on the mother, when they are destroyed by animals or by insects, as she is unconscious of their destruction.

Fourthly, as all animal existence must perish in process of time, by the inirritability and consequent debility occasioned by the repetition of stimulus, which is termed habit, and appears to be an universal law of nature : it is so ordered, that as soon as any organized being becomes less irritable and less sensible, and in consequence feeble or sickly, that it is destroyed and eaten by other more irritable and more sensible, and in consequence more vigorous organized beings ; as insects attack the weaker vegetable productions in preference to the healthy ones ; and beasts of prey more easily catch and conquer the aged and infirm, and the young ones are defended by their parents. By this contrivance more pleasureable sensation exists in the world, as the organized matter is taken from a state of less irirritability and less sensibility, and converted into a state of greater ; that is in other words, that the old organizations, whether stationary or locomotive ones, are transmigrated into young ones : whence it happened, that before mankind introduced rational society, and conquered the savage world, old age was unknown on earth !

Finally, the aged and infirm, from their present state of inirritability and insensibility, lose their lives with less pain, and which ceases instantly with the stroke of death ; inasmuch that death cannot so properly be called positive evil, as the termination of good.

To

To this should be added, that a long continued or a great excess of pain cannot afflict an organized being; as syncope or sudden death, and consequent decomposition, attends very violent pains; and a lingering death attends the continuation of less violent ones. Hence it becomes a consoling circumstance, that misery is not immortal.

A philosopher, whom I left in my library, has perused the above paragraphs, and added the subsequent one to my manuscript. “It consoles me to find, as I contemplate with you the whole of organized nature, that it is not in the power of any one personage, whether statesman or hero, to produce by his ill-employed activity so much misery, as might have been supposed. Thus, if a Russian army, in these insane times, after having endured a laborious march of many hundred miles, is destroyed by a French army in defence of their republic, what has happened? Forty thousand human creatures dragged from their homes and their connexions cease to exist, and have manured the earth; but the quantity of organized matter, of which they were composed, presently revives in the forms of millions of microscopic animals, vegetables, and insects, and afterwards of quadrupeds and men; the sum of whose happiness is perhaps much greater than that of the harassed soldiers, by whose destruction they have gained their existence!—Is not this a consoling idea to a mind of universal sympathy?”

“I well remember to have heard an ingenious agricultor boast, that he had drained two hundred acres of morassy land, on which he now was able to feed a hundred oxen; and added, ‘is not that a meritorious thing?’ ‘True,’ replied one of the company, ‘but you forget, that you have destroyed a thousand free republics of ants, and ten thousand rational frogs, besides innumerable aquatic insects, and aquatic vegetables.’”

“Having written the above, I fear you may think me a misanthrope, but I assure you a contrary sensation dwells in my bosom; and

and though I commiserate the evils of all organic being, *Homo sum, humani nihil a me alienum puto.*”

2. The vascular systems of animal bodies are excited into action by the stimulus of the fluids, which they absorb, circulate, and secrete; and when this action is exerted in its natural or most usual quantity, it is attended with agreeable sensation, which constitutes the pleasure of organized existence. These vascular actions of animals, which perform digestion, sanguification, and secretion, convert the aliment, after its solution in the stomach, into more compounded and more solid materials; as into muscles, membranes, nerves, bones, and shells; at the same time that pleasurable sensation attends this activity of the system. The vascular actions of vegetables, which perform their digestion, sanguification, and secretion, convert the elements of air and water, or other aliments, which they receive from organized matter decomposing beneath the soil, into more compounded or more solid materials, as into vegetable vessels, muscles, membranes, nerves, and ligneous fibres; and a degree of pleasurable sensation must be supposed from the strongest analogy to attend this activity of their systems.

3. Many of the materials, which have been thus produced by the digestion and secretion of organized beings, and have given pleasure in their production, have been slow in their decomposition after the death of the creature; as the shells of fish were originally thus formed, and were left at the bottom of the ocean, till they became wonderfully accumulated, were afterwards elevated by submarine fires, and constitute at this day the immense rocks and unmeasured strata of limestone, chalk, and marble. As mentioned in Sect. X. 10. 1.

The strata, which are incumbent on the calcareous ones, which consist of coals, sand, iron, clay, and marl, are all of them believed to have been originally the products chiefly of vegetable organization; whatever changes they have since undergone in the long progress

progreſs of their decomposition, and that all thoſe ſolid parts of the earth have been thus fabricated from their ſimpler elements by vegetable and by animal life, and have given pleaſure to thoſe organized beings, which formed them, at the time of their production.

We hence acquire this ſublime and intereſting idea; that all the calcareous mountains in the world, and all the ſtrata of clay, coal, marl, ſand, and iron, which are incumbent on them, are MONUMENTS OF THE PAST FELICITY OF ORGANIZED NATURE!—AND CONSEQUENTLY OF THE BENEVOLENCE OF THE DEITY!

VIII. *The Cultivation of Brocoli.*

Translated in part from an elegant Latin poem of Edward Tighe, Eſq.

THERE are of learned taſte, who ſtill prefer
 Coſ-lettuce, tarragon, and cucumber;
 There are, who ſtill with equal praiſes yoke
 Young peas, aſparagus, and artichoke;
 Beaux there are ſtill with lamb and ſpinach nurs'd,
 And clowns eat beans and bacon, till they burſt.

This boon I aſk of Fate, where'er I dine,
 O, be the Proteus-form of cabbage mine!—
 Cale, colewort, cauliflower, or ſoft and clear
 If BROCOLI delight thy nicer ear,
 Give, rural Muſe! the culture and the name
 In verſe immortal to the rolls of Fame.

When the bright Bull aſcending firſt adorns
 The Spring's fair forehead with his golden horns;

When the bright Bull, 19th of April.

Italian

Italian seeds with parsimonious hand
 The watchful Gardener scatters o'er his land ;
 Quick moves the rake, with iron teeth divides
 The yielding glebe, the living treasure hides ;
 O'er the smooth foil, with horrent thorns beset,
 Swells in the breeze the undulating net ;
 Bright shells and feathers dance on twisting strings,
 And the scar'd Finch retreats on rapid wings.

Next when the Twins their lucid forms display,
 And hand in hand salute the lord of day ;
 When climbs the Crab the blue ethereal plain,
 Or shakes the Lion his refulgent mane ;
 Each passing month renew the grateful toil,
 Upturn with shining blade the fertile soil ;
 New seeds insert, whose vegetable birth
 May rise successive from the womb of earth.
 So shall hibernal hours on frozen wing
 View the green products of the breezy spring ;
 Admiring nymphs the genial banquet share,
 Smile on thy labours, and reward thy care.

But when three leaves the young Aspirer shoots,
 To other soils transplant the shorten'd roots ;
 Where no tall branches form a vaulted glade,
 Nor ivy'd tower projects a length of shade ;
 There in wide ranks thy verdant realms divide,
 Parting each opening file a martial stride.
 There with charm'd words of some poetic spell
 Call the blue Naiads from their secret cell ;
 From silver urns in lucid circles pour
 Round each weak stem the salutary shower.

Pants thy young heart to grasp the laurel'd prize,
 And swell thy Brocoli to gigantic size ?—

The Twins, 20th of May.

The Crab, 20th of June.

The Lion, 22d of July.

Soon as each head with youthful grace receives
 The verdant curls of six unfolding leaves ;
 O, still transplant them on each drizzly morn,
 Oft as the moon relights her waning horn ;
 Till her bright vest the star-clad Virgin trails,
 Or corn-crown'd Autumn lifts his golden scales.
 Then ply the shining hoe with artful toil,
 Ere the grey night-frost binds the stiffen'd soil ;
 And, as o'er heaven the rising Scorpion crawls,
 Surround the shuddering stems with earthen walls.
 So shall each plant erect its leafy form,
 Unhook by Autumn's equinoxial storm ;
 And round and smooth, with silvery veins emboss'd,
 Repel the dew-drops, and evade the frost.
 Thus on the Stoic's round and polish'd brows
 Her venom'd shafts in vain misfortune throws ;
 By virtue arm'd, he braves the tented field,
 The innocuous arrows tinkling on his shield.

Hence when ascendant rules the watery Star,
 Or the celestial Fishes swim in air,
 Thy guarded stalks shall lift their curled heads,
 And fringed foliage shade thy ample beds,
 Gem with bright emerald Winter's trackless snows,
 Or bind with leafy wreaths his icy brows.

When leads the Spring amid her budding groves
 The laughing graces, and the quiver'd loves ;
 Again the Bull shall shake his radiant hair
 O'er the rich product of his early care ;

The star-clad Virgin, 22d of August.

Golden scales, 22d of September.

Scorpion, 22d of October.

Evide the frost. One advantage, which vegetables receive by repelling the water by the upper surfaces of their leaves, is, that it may not incommode their respiration ; but another is, that by not being thus moistened they are less injured by frost:

Watery Star, 19th January. Celestial Fishes, 17th February. The Bull, 19th April.

With

With hanging lip and longing eye shall move,
And Envy dwell in yon blue fields above.—

Oft in each month, poetic Tighe! be thine
To dish green Brocoli with savory chine;
Oft down thy tuneful throat be thine to cram
The snow-white cauliflower with fowl and ham!—
——Nor envy thou, with such rich viands blest,
The pye of Perigord, or Swallow's nest.

The pye of Perigord was made of the red-legged partridges before the French revolution; and was sold in London at the price of a guinea for each bird it contained.

Swallow's nest. There is a species of swallow, that builds a nest on the banks of the Nile and Ganges, which consists of isinglass; which the bird collects from putrid fish left on the sands; and which is esteemed a great delicacy, and enters the most costly soups at the luxurious tables of the east.

S E C T. XX.

PLAN FOR DISPOSING PART OF THE VEGETABLE SYSTEM OF LINNEUS
INTO MORE NATURAL CLASSES AND ORDERS.

- I. The classes of plants distinguished by the proportion or situation of the stamina are more natural than those distinguished by their numbers. Many Linnean classes thus distinguished. Many of the orders are natural classifications. Use of natural classes. 2. The situation and proportion of the sexual organs are less liable to variation than their numbers. Great variation in respect to number of the stamina. From luxuriant growth. Some species have but half the number. Others have part of them without anthers. The number of pistilla varies in different species of the same genus. Progress of nature to greater perfection. Of the class Syngenesia. 3. Immutable parts discovered by reasoning as well as by observation. Filaments of *Meadia* unchangeable, and of *hemerocalis fulva*, *nigella*, *collinsonia*, *spartium*. 4. Some natural orders might become classes. As the grasses, and the umbellatæ, and stellatæ. Forms of the filaments, and of the anthers, as well as their situations, less variable than their numbers. 5. Classic characters. From short and long filaments. From their unequal heights. From their different insertions. From their respective situations. From their adhesions to each other. Or to the corol, or style. From their existence in different flowers. From the connexion of the anthers, or from the forms of the filaments and anthers. 6. Uncertainty of the number of pistilla. Their proportions and figures less variable. And would define more natural orders. 7. Characters of orders from the length of the style. The curvature of it. The attitudes of it. Divisions of the stigma. Absence of the stigma. Adhesions of the style. 8. Conclusion.

I. OFTEN as I have admired the classification of vegetables by the great Linneus deduced from their sexual organs of reproduction,
some

some of the classes have appeared to me to be more excellent than others, as they seemed to approach nearer to natural ones. On further attention to this subject, I perceived that those classes, which were deduced from the proportions or situations of the stamina, or which included the number of the stamina along with their proportions and situations, were more natural classes than those, which were distinguished simply by the number of them.

Thus the classes termed Dydynamia and Tetradynamia, which are derived from the proportions and situations of the stamina as well as their number, are wonderfully natural; to which may be added the classes Icosandria, and Polyandria, as their diagnostic character consists in the situation of the stamina on the calyx or petals in the former class, and on the receptacle in the latter, though the names of these classes are not so happy, as they simply refer to their numbers, which are unfortunately very variable.

Some other of the Linnean classes are distinguished by the situation of the filaments, as the Monadelphia, Diadelphia, Polyadelphia, and Gynandria; all which approach towards natural classes; and the Syngenesia, which is distinguished by the adhesion of the anthers, is a class beautifully natural, except the last order.

Many of the orders also in the sexual system are natural classifications, as the grasses in the class Triandria, the umbellated plants in the class Pentandria, and perhaps the cruciform plants in the class Tetandria; with many amongst those which are termed natural orders at the end of the Genera Plantarum; all which might probably be discriminated by some situation, or proportion, or form, of their respective stamina.

As the classes deduced from the proportions or situations of the stamina alone, or conjointly with their respective number, appear thus to produce more natural distributions of vegetables, than those derived simply from their number; it might have been more fortunate for the science of Botany, if the great author of the sexual system

system had turned his mind to have classed all of them from the proportions, situations, and forms of the stamina alone, or from these conjointly with their number, and to have distinguished the orders according to the proportions, situations, or forms of the pistilla alone, or conjointly with their numbers.

The great use of distributing plants into natural classes is not only for the purpose of more readily distinguishing them from each other, and discovering their names, but also for that of more readily detecting the virtues or uses of them in diet, medicine, or the arts; as for the purposes of dying, tanning, architecture, ship-building; which has already been happily experienced in attending to the genera or families of plants, which are all natural distributions of them, whence the same virtues or qualities generally exist among all the species of the same genus, though perhaps in different degrees.

2. But another great advantage would probably occur from deducing the characters of the classes of vegetables from the situations, proportions, or forms of the sexual organs rather than from their number; which is, that these criterions of the classes and orders would be much less subject to variation.

The variation of the number of stamina not only frequently occurs from the too luxuriant growth of many cultivated flowers, or by the duplicature or multiplication of their petals, or nectaries, which is liable much to inconvenience the young botanist; but several of the species of plants have but half the number of stamina, which other species of the same genus possess. This occurs so frequently, that the defect of number is expressed as an essential character of the species in many instances. Thus the *cerastium pentandrum*, and *spergula pentandra*, distinguish those species from the other plants of the genus, which possess ten stamens; so *tamarix floribus pentandris*, *tamarix floribus decandris*, *salix floribus diandris*, *salix triandra*, *salix pentandra*, *valeriana floribus monandris*, *valeriana floribus diandris*, *verbena diandra*.

So the vernal flowers of the *corchorus filiquosus* have but four stamina, but the autumnal ones have numerous stamina. The *linum* flax of this country has but five perfect stamina, and five without anthers on their summits; whereas the *linum lusitanicum*, Portugal flax, possesses ten complete ones. The *verbena*, vervain, of our country has four stamina, that of Sweden but two; the genus *albuca*, *bignonia catalpa*, *gratiola*, and hemlock-leaved *geranium*, have only half their filaments crowned with anthers; all which and many others evince the uncertainty of depending on numbers alone for distinguishing the classes of plants.

Nor are the number of pistilla more certain as a criterion of the orders. Thus there is *nigella pentagyna*, and *nigella decagyna*; *hypericum floribus pentagynis*, *trigynis*, and *digynis*, with innumerable other similar instances, as mentioned in No. 6 of this Section. Which evince, that great confusion must be occasioned by a reliance simply on the number of the pistilla for defining the orders of plants.

I contend, that the number of the sexual organs in flowers is more liable to change by the influence of soil or climate, or by the progress of time, than their situations or proportions, or forms, and might therefore probably be more advantageously employed in distinguishing their classes and orders from each other, as well as in rendering them more natural combinations.

This mutability or uncertainty of the number of the organs of reproduction belonging to individual flowers, would seem to arise from an attempt of all organized beings towards greater perfection. Whence as the success of the process of reproduction becomes more certain from the greater perfection of the vegetable being, the organs for the purpose of reproduction seem to become fewer. Whence some flowers have lost half the stamina, and in others the anthers of those stamina are yet only deficient, and in others the pistilla are deficient; all which in process of time may gradually become less numerous,

numerous, or separate themselves from hermaphrodite flowers into sexual ones, as in the classes of monœcia and diœcia; and all of them finally, after a long process of ages, become of the orders monandria and monogynia of those classes; whilst new kinds of vegetables may begin a similar progress from less to greater perfection. So in animals, the less perfect seem to possess organs for a more numerous reproduction, as fish and insects. Such would seem to be the perpetual progress of all organized being from less to greater perfection existing from the beginning of time to the end of it! a power impressed on nature by the great Father of all.

Thus in the class syngenesia, the tendency of these vegetables from more numerous to a more simple organization for the purpose of reproduction is wonderfully conspicuous. In the order polygamia æqualis, all the florets are furnished with male and female organs. In the order polygamia superflua, the florets in the centre have both male and female organs, those in the circumference have only female ones; and of those some have lost the corol of the floret. In the order polygamia frustranea the florets in the centre possess both male and female organs, but those in the circumference have neither; though at the same time the corols of those florets remain. And lastly, in the order polygamia necessaria the central florets are simply male florets, and those in the circumference simply female ones; and thus approach to the class of monœcia, having the male and female organs in separate florets; and may in process of time exist in separate flowers, and afterwards in separate plants, like the two sexes of the more perfect animals. Something similar to this seems already to have occurred in the plant *phytolacca*, of the class decandria decagynia; which possesses one species with twenty males, another with ten, another with only eight males and eight females, and lastly one of the class diœcia, or two houses.

3. In many flowers some circumstances of the situations or proportions or forms of the filaments or anthers may be shewn, by rea-

soning as well as by observation, to be less mutable than others ; as the shortness of the filaments of dodecatheon meadia, cyclamen, solanum, borago, fuschia, and others. As mentioned in Botanic Garden, Vol. II. note on Meadia. Thus in the flower of meadia the filaments are exceedingly short compared to the style, and seem to have been in that circumstance immutable. Whence it became necessary, first to furnish them with long anthers, which stand pointed towards the distant stigma apparently endeavouring to reach it. Secondly, it was necessary to bend the flower-stalks, when the corols open into those graceful curves, which constitute the uncommon beauty both of this flower and of the fuschia ; that the stigma by hanging down immediately beneath the anthers might thus receive, as it falls, the prolific farina. And that this was the evident design of the curvature of the flower-stalk appears from its rising again, and becoming quite erect, as soon as the impregnation of the pericarp is accomplished. Thirdly, as the flower thus becomes perpendicularly pendent, it was necessary to reflect the petals for the purpose of admitting light and air to the sexual organs.

We may reason from this structure of the meadia, that all this apparatus of long erect anthers to approach the stigma ; of bending the flower-stalk, that the sexual organs might become pendulous ; and then of reflecting the petals to give light and air ; might have all been spared, if the filaments alone could have grown as long as the style ; as occurs in most other flowers. And that therefore in these flowers the filaments are the most unchangeable parts of them ; and that hence the comparative length of the filaments in respect to the style would afford the most immutable mark of their essential character, or for the purpose of classification.

Another apparent instance of the great unchangeableness of the length of the filaments exists in the *hemerocallis fulva*, tawny day-lily, in which I observe the style is crooked, or bent into a zigzag, about the middle of it, evidently for the purpose of shortening it,

that the anthers might approach the stigma ; the stalk of the flower not being so flexible as to allow it to become pendent, as in the *hemerocallis flava*, or yellow day-lily.

In *nigella*, devil in the bush, the styles are very long compared with the filaments, and bending down their stigmas over the anthers in curves, give the flower a resemblance to a regal crown ; which need not to have occurred, if the filaments could more easily have been lengthened.

In *collinsonia* the two anthers stand widely diverging on short filaments, and the tall capillary style bends its stigma into contact first with one of them, and afterwards with the other. In the *spartium scoparium*, common broom, the long style bends round into a circle to accommodate the stigma to the short set of anthers, which great curvature need not have existed, if the filaments could more easily have grown longer. Other instances of similar structure are related in Sect. VII. 2. 2. of this work.

It is probable, that similar observations, and a consequent reasoning on them, might be applied to many other kinds of flowers so as to detect the most unchangeable parts of them : but great time, labour, opportunity, and ingenuity, would be required to establish from them the most invariable and most natural classes of vegetation.

4. Many different proportions and situations and forms of the filaments are enumerated in the *Philosophia Botanica* of Linnæus ; some of which might possibly have become classical characters, if he had turned his attention to them, and given them adapted names ; as he has done to those classes, which he has derived from the situations of the sexual organs, as *didynamia*, *tetradynamia*, *syngenesia*, and others, which approach nearer to natural classes, and are subject to less variation than the numerical ones.

Some of those collections of plants, which Linnæus has termed natural orders, and some of those of Ray, and Tournefort, might

perhaps have had names affixed to them, denoting the situations or proportions or forms of their stamina, and have thus constituted natural classes in the Linnæan system. Thus for example the natural order of grasses might perhaps have had a name denoting their long capillary filaments. The natural order of grasses is so conspicuous, as to have struck all beholders; they constitute, it is said, nearly a sixth part of the vegetable kingdom, especially in open countries; the leaves are not easily broken by being trampled on, but die in winter, becoming yellow and dry; but what is wonderful, they are said to revive in the spring, and become green again. This natural order of plants has been divided into *cereal* and *gramina*, corn and grasses; which however only differ in respect to the size of the seeds. It is much disunited by the numerical distinctions of the sexual system, as some grasses belong to the class *monandria*, *diandria*, *triandria*, and *hexandria*; and those of the *triandria*, and *hexandria*, are either *hermaphrodite*, or *monœcious*, or *polygamous* plants. Of these a very curious and extensive table is given in the *Prælectiones in Ordin. Natur.* a Giseke Hamburg. 1792, p. 138.

A great part of the natural order of *caryophyllei*, in which the number of the stamina is very variable, are observed by Mr. Milne to have their filaments alternately attached to the claws of the petals and to the receptacle, and might possibly have a classical denomination from that circumstance. *Botan. Dic. Art. Caryophyllei.*

The five stamina of the umbellated plants in the class of *pentandria digynia*, with five petals, two seeds, above; which are termed *umbellatæ* in the natural orders of Linnæus; as they diverge from each other, might perhaps be called five starred, or cinque-pointed stamina from this situation. And in part the natural order of plants termed *stellatæ* by Linnæus, as *galium*, and *asperula*; which belong to the class *tetandria monogynia* with one petal, two berries, above; the four diverging stamina might perhaps be termed *cruciform*, as they oppose each other. And thus these natural collections of vege-

tables might acquire a classical denomination from the situations of their stamina, or perhaps from the form of their filaments or anthers.

To these situations and proportions of the stamina, with many others, might be added the form of the filaments, as capillary, flat, wedgeform, spiral, awled; and also the forms and situations of the anthers, as globular, oblong, arrowy, angular, horned. Which may be seen in the *Philosophia Botanica* of Linnæus, p. 65; or a translation of them in Miln's *Botanical Dictionary*, under the titles of filament and anther. All which, I suppose, are much less variable by soil or climate, than the numbers of their respective sexual organs, and would in the hands of an ingenious botanist form more natural classifications.

5. Classical characters might perhaps be taken from the length of the filaments compared to that of the style, with some other concomitant circumstances; as first where they are somewhat shorter than the style, as in the pendent bell-flowers of lily, fritillaria, campanula. Secondly where the filaments are more than twice as short as the style, as in meadia, cyclamen, solanum, borago, fuschia. Or thirdly where the filaments are more than twice as long as the style, and in the natural order of grasses.

Secondly, the unequal heights of the filaments at the first opening of the corol. In many flowers the inferior set of stamina rise up to the stigma, when the higher set have discharged their pollen. To these situations of the stamina may also be added their number, as in the two very natural classes of Linnæus, the didynamia and the tetradynamia. One of these might be termed two higher than two; the other four higher than two. To which might perhaps be added a third class, of many higher than many; as six above six in lithrum falicaria, five above five in lychnis.

Thirdly, the different insertions of the filaments, as first on the calyx, which principally distinguishes the class icosandria of Lin-

næus, and which thus approaches towards a natural class. Secondly on the receptacle, which distinguishes the class polyandria of Linnæus, which also approaches toward a natural class. And thirdly, the insertion of the filaments alternately to the claws of the petals, and to the receptacle; which distinguishes a part of the natural order of the caryophyllei, in which the number of the stamina is very various.

Fourthly, the situation of the filaments in respect to each other; as first in the natural order of Linnæus termed stellatæ, or a part of the tetrandria monogynia; the diverging filaments oppose each other, and might be termed cruciform, as in galium, asperula. Or secondly, where five diverging filaments assume the appearance of a star, as in the natural order of umbellatæ, or a part of pentandria digynia, and might have a name borrowed also from their number, like five-starred, or cinque-pointed, applied to the filaments, as mentioned above.

Fifthly, the adhesions of the filaments to each other at their base. This has given names to three classes of the Linnæan system, which approach to natural ones, under the term of brotherhoods; as first, where the filaments all adhere at their base, as in the class monadelphica; secondly, where they adhere in two sets, as in the class diadelphica; and thirdly, where they adhere in many sets, as in the class polyadelphia.

Sixthly, the adhesions of the filaments to the corol, as where they adhere more than half their length to the internal part of it, as in many monopetalous flowers, as primula, auricula; or where the filament arises from the petal, or where the anthers adhere to the margin of the petal, as in many of the natural order of scitamineæ, as observed in the Prælect. in Ord. Natur. a Giseke, p. 189.

Seventhly, where the filaments adhere to the style, as in the class gynandria, which approaches to a natural one.

Eighthly, the situations of the stamina not in the same flowers with

with the pistillum. This has also given names to three classes of the Linnæan system, monœcia, diœcia, polygamia.

Ninthly, the connexion of the anthers, which has given the name to the class syngenesia, which excepting the last order, is a wonderfully extensive and natural class.

To these varieties of situation, proportion, and adhesion, of the filaments, may be added those of the anthers on their summits; which to an attentive observer may perhaps be as numerous as those of the filaments, and to these may again be added the various forms of the filaments, as capillary, flat, wedgeform, spiral, feathered, &c. and also the various forms of the anthers, as oblong, globular, arrowy, angular, horned. All which are described in the *Philosophia Botanica*. And by an adoption of some of these separately or in conjunction for classical characters, I should hope that new classifications might be discovered instead of those, which are simply numerical. Which might be more natural ones, less subject to variation, easier to be distinguished from each other, and more similar in their good or bad qualities; and might thus add to the great beauty and utility of the present wonderful arrangement of so many thousand vegetables in the Linnæan system.

6. The same observations and mode of reasoning are applicable to the various orders of the sexual system. Which if the great Linnæus had fortunately deduced them from the proportions, situations, or forms of the styles and stigmas, the characteristic signs might have been less liable to change by soil or climate, and many of the orders have been more natural collections of vegetables, than those are, which he has derived simply from their number.

The uncertainty of the number of pistilla, and the confusion, which might be occasioned by a reliance on it, was mentioned in No. 2 of this section; there is a *nigella pentagyna*, and a *nigella decagyna*; there is an *hypericum floribus pentagynis*, *trigynis*, and *digynis*; and in the whole order of frustraneous polygamy in
the

the class syngenesia the florets of the ray are furnished with a style and no stigma, as in the sunflower.

The flowers of the polygonum, whose classical character is octandria, and its order trigynia, affords many instances of the uncertainty of the number of the sexual organs, both in respect to the stamina and pistilla. Thus the species 4, 5, 6, 7, possess but five stamina in each; the species 8, 9, 10, have each of them six stamina, and the eleventh species has seven stamina. And lastly the species 4, 5, 6, 8, 9, 11, 12, have each of them but two pistilla, and all the rest three pistilla.

From these and other innumerable instances there is reason to conclude, that the proportions, situations, and forms of the style and stigma, to which might be added their number conjointly, would have made essential characters for the orders, which would have been less variable than those derived only from the number of them, and would have rendered them more natural collections.

7. The characters of the orders might be deduced first from the length of the style compared with that of the filaments; as where the style is more than twice as long as the filaments, as in meadia, cyclamen, solanum, fuschia. Secondly, where the style is about one third longer than the filaments, as in lilium, fritillaria, campanula; and many other bell-flowers. Thirdly, where the style is very short compared to the filaments, as in poppies.

2. The characters of the orders might be deduced from the curvatures of the style. As first, where the style bends into a curve over the anthers to bring the stigma into contact with them, as in nigella, devil in the bush. Secondly, where the style bends into a circle like a french-horn to accommodate the stigma to two sets of stamina in succession, first the lower, and then the higher, as in spartium scoparium, common broom. Thirdly, where the style is crooked in the middle of it, making a kind of zigzag, to lower the stigma

stigma to the anthers beneath it, as in *hemerocallis fulva*, tawny day-lily.

3. Characters might be deduced from the attitude of the style; as where it is pendent, that the stigma may be accommodated to the anthers above it, as in many bell-flowers. Secondly, where it is inclined at a considerable angle to accommodate the stigma to the inclined anthers, as in *epilobium*, willow-herb, and *gloriosa superba*. Thirdly, where the style is erect, to adapt the stigma to the upright anthers, as in many flowers.

4. Where the divisions of the stigma expand, and bend down toward the anthers beneath them, as in some kinds of *dianthus*, pink, and in *epilobium*.

5. The total absence of the style might mark an order.

6. The total absence of the stigma, which is a characteristic mark of the florets of the ray in the order frustraneous polygamy of the class syngenesia.

7. Where the style adheres to the stamina, as in the natural order of Linnæus termed *calamariæ*, as observed in *Philos. Botanica*, No. 102, on the *Pistilla*, p. 68.

8. Where the style supports the stamina as in the class gynandria.

9. Where the style appears to exist both above and below the germ, as in *capparis*, *euphorbia*.

10. The lateral adhesion of the style to the germ, as in one of the natural orders of Linnæus, which he has termed *senticosæ*, or briers, which includes the rose, raspberry, strawberry, agrimony, alchemilla, and many others, which might be named from the lateral adhesion of the style to the germ, which Linnæus asserts to exist both in the natural order above mentioned, and in the order *Icosandria polygyna*. *Philos. Botan.* p. 67.

If to these proportions or situations of the style were added the varieties

rieties of its figure, as cylindrical, angular, awled, capillary; and to these were again added the divisions of the stigma, as convolute, revolute, six-parted, many-parted. And to these were again added the various forms of the stigma, as globular, egged, end-nicked, cruciform, feathery, &c. which are enumerated in the *Philosophia Botanica*; there is great reason to believe, that characteristic marks of all the orders of plants might be deduced and named from some of those circumstances separately or conjointly; which might distinguish them from each other with greater ease and certainty, and by marks less variable by soil or climate, than by the number alone; and by rendering them more natural add to the beauty and utility of the Linnæan system.

Conclusion.

Nevertheless I am well aware of the great general inconvenience of altering so extensive a system once established, and am sorry to see some idle efforts to add the classes already deduced from situation or proportion to those, which are simply numerical; and thus rather to deteriorate than to improve the present system of the great master.

I profess myself incapable to execute the plan, which I have here suggested, as it would require a most exact knowledge of the detail of botany, as well as of the outline; would require many years of unremitting application, with every opportunity of visiting botanic gardens, or examining dry collections, and inspecting prints and drawings of vegetables; and would demand a genius, which few possess, capable of reducing the complex and intricate to the simple and explicit.

But if the system of the great Linnæus can ever be intrinsically improved, I am persuaded, that the plan here proposed of using the situations, proportions, or forms, with or without the numbers of

the sexual organs, as criterions of the orders and classes, must lay the foundation; but that it must require a great architect to erect the superstructure. And my principal design in adjoining this imperfect sketch at the end of this work was to warn those botanists, who have begun to interweave some of the Linnæan classes deduced from situation or proportion of the sexual organs into those distinguished simply by number, that they so far contribute to deteriorate the great system, which they mean to amend.—At the same time I much applaud, and beg leave to recommend to the attention of the public, the superb picturesque botanical coloured plates now publishing by Dr. THORNTON, which I suppose have no equal.

ADDITIONAL NOTES.

1. *To be inserted before the last paragraph of Sect. IV. 2. 1. at p. 45, line 22.*

IN the present year 1799, August 18, there was an uncommon summer-flood on the Derwent, which covered my garden above three feet deep with muddy water. Many plants of the rheum hybridum, mule rhubarb, which were transplanted in the spring, and had not flowered, had their large pointed leaves covered with mud, so as to render the green colour totally invisible after the water subsided. They appeared strong as before for a day or two, and then every one withered and dropped down. The same happened to the leaves of many other vegetables, and to espallier apple-trees, as high as they were immerged; which was doubtless owing to their respiration being precluded by the veil over them of a fine tenacious mud. See Sect. VII. 2. 6.

2. *To be inserted in Sect. VII. 2. 6. at p. 115, after line 23.*

The rheum hybridum, mule rhubarb, described in Murray's *Systema Vegetabilium*, edition the fourteenth, I believe to be produced between the palmated rhubarb, and the common rhubarb of our gardens, or rheum raphonticum; as it appeared both in my garden

and my neighbours amongst a mixture of those two kinds of rhubarb, without being previously placed or sown there. The leaf is very large and pointed, without being palmated, and is a week or two forwarder in the spring than either of the other rhubarbs, and the peeled stalks are asserted by connoisseurs in eating to make the best possible of all tarts, much superior to those of the palmated or raphontic rhubarb; and are so much more valuable as a luxury, as they precede by a month the gooseberry and early apple; and may be well propagated by dividing the roots, as they do not produce seed in all summers. See Sect. IV. 2. 1.

3. *To be inserted at the end of Sect. X. 4. 9. p. 207.*

Mr. Ruckert planted two beans in pots of equal size filled with garden-mould; the one was watered almost daily with distilled water, and the other with water impregnated with carbonic acid gas, in the proportion of half a cubic inch to an ounce of water; and both of them were exposed to all the influence of the atmosphere except to the rain. The bean treated with the carbonic acid water appeared above ground nine days sooner than that moistened with distilled water, and produced twenty-five beans; whereas the other pot produced only fifteen. The same experiment was made on stock-july flowers, and other plants with equal success. An. Chym. 1788.

4. *To be inserted at the end of Sect. X. 7. 7. p. 228.*

Besides which the vitriolic acid abounding in many clays, when brought into contact with mild calcareous earth, by the various operations of agriculture, must unite with it, and set at liberty the carbonic acid either in a fluid form, or a gaseous form beneath the soil;

which is known to be so friendly to vegetation, when applied to the roots of plants; and at the same time a gypsum will be produced, which is now also believed to be useful in agriculture.

Mr. Kirwan asserts, "That the gypsum used with success in agriculture is of a fibrous texture; and that clay lands, he believes, to be more improved by it than calcareous ones. The time of spreading it is in February or March, and it is then to be thinly strewed on grass-land at the rate of about eight bushels to an acre; as more he says would be hurtful." He further adds that the theory of its effects is to be deduced from its extraordinary sceptic power; as it is found to accelerate putrefaction in a higher degree than any other substance, (*Histoire de Putrefaction*, p. 36), whence it is not to be ploughed in, but barely to be strewed on the surface of the land in the month of February, to convert the old grass quickly into coal to nourish the young growths."

I have transcribed the above from Mr. Kirwan's *Treatise on Manures*, but am liable to doubt the experiments concerning bodies promoting putrefaction; as the progress of that process has generally been only judged of by the odour; which may possibly be altered or destroyed by many bodies, by their uniting with it without otherwise affecting the tendency to dissolution. Add to this another circumstance, shewing the uncertainty of these deductions, that some of these antiseptic materials, as sea-salt, and lime, are said to promote putrefaction, when used in small quantities; and to suppress it, when used in large ones.

5. *To be inserted in Sect. XIII. 2. 2. at the end of the paragraph which mentions Mr. Lawrence's letter to Mr. Bradley.*

Another thing, which renders low situations less proper for gardens, is, that I believe them to be much more liable to be infested by

by the aphid ; as leaves of the nut-trees in my garden on the banks of the Derwent are every year crowded with innumerable aphides on their inferior surfaces, and yet I have seen few, if any of them, on nut-trees in some higher situations, which I happened to inspect. Add to this, that the great honey-dew, mentioned in Sect. XIV. 1. 7. was produced on a row of willows by the side of water. This may nevertheless be in part ascribed to some other local circumstance ; as I this year observed numerous large black aphides round the stalks of garden-beans on a clayey soil, which did not exist in my garden, which may be called a carbonic soil. Though on the peach and nectarine trees, against the walls in my low garden, and on some plum-trees, the aphides exist almost every year in such destructive multitudes as to prevent the fruit from succeeding, and thence to render them not worth cultivation ; and to render the leaves of the nut-trees less in size, and less prolific than other nut-trees on a more elevated and clayey soil, with which I this year compared them.

Why the aphid should be so much more numerous in moist situations is a curious subject of inquiry, but is so similar to another animal fact, that they may illustrate each other. The cough and consequent consumption of sheep, which occurs annually in moist situations, is owing to an insect called a fleuk-worm, about the size and shape of a child's finger-nail, which creeps up the gall-ducts from the intestines, and preys upon the livers of sheep ; as may be seen in moist seasons in our shambles. This seems to occur from the bile becoming too dilute from so much watery nourishment in those animals, and that thence it does not possess sufficient bitterness or acrimony to prevent the depredation of these insects, as in drier seasons. On the same account I suspect the juices of nut-trees and of willows planted in very moist situations may be rendered too dilute ; but that in higher situations they may possess sufficient acrimony or bitterness mixed with the sap-juice to prevent the depredations of the aphid. See Sect. XIV. 2. 8.

6. *To be inserted at the end of Sect. X. 5. 3.*

Phosphorated lime is said to be found in the greatest quantity in wheat, where it contributes to the formation of the gluten, which is thence not improperly denominated by some writers animal gluten; which in rainy years has been observed by Witwer to be in smaller quantity Differt. II. p. 103. Hence the use of bone-ashes as a manure for wheat, as observed by Mr. Kirwan. Essay on Manures, p. 53.

7. *To be inserted at the end of Sect. VI. 10.*

Besides the various secretions above described Brugmanns is said by Humbolt to have shewn, that plants void an excrement like animals, which might be noxious to them, if retained; that he put the plant, lolium, ray-grass, into a glass of water, and observed daily at the extremities of the roots a small drop of a viscous material; which he detached and found to be renewed on the next day. But this I suspect to have been produced by the death and consequent decomposition of the extremities of the roots in their unnatural situation. Journ. de Physique Delametherie, T. IV. p. 388.

8. *To be inserted at the end of Sect. XIV. 4. 2.*

In the Transactions of the American Philosophical Society there is a paper shewing, that the water-rats of that part of the country are so liable to be affected with tape-worm, as is supposed much to diminish their numbers. In this country many animals, as I believe dogs, cats, and geese, as well as the human species, are afflicted with this intestine enemy. Could some of these diseased American rats be

imported into this country, and propagate their malady amongst the native rats of this climate?

9. *To be inserted at the end of Sect. X. 7. 8. p. 228.*

Having now spoken of carbon, of lime, and of clay, which with siliceous sand constitute the principal ingredients of fertile soils, some rules may be required for distinguishing the goodness of soils by the purchaser, as well as by the possessor. For this purpose the chemical analysis would first present itself, as attempted by Fordyce, many years ago, and lately by Giobert, Bergmen, Kirwan, and others.

M. Giobert found, that one pound of a fertile soil in the vicinity of Turin contained of carbonic matter, which would burn and flame, about twenty-five grains, of flinty sand about 4400 grains, of clay about 600 grains, of lime about 400 grains, and lastly, of water about 70 grains. The same author found that one pound of some barren soils was composed of siliceous earth about 3000 grains, of argillaceous earth about 600 grains, and of calcareous earth about 400 grains, and I suppose without any carbonic matter.

Mr. Kirwan ingeniously observes, that the quantity of moisture, which some countries are more liable to than others, should be nicely attended to, at the same time that you estimate the fertility of land by its analysis, as moist climates or situations may require more sand than drier ones; and therefore the same component parts of soil would not be the most fertile, on both the western and eastern coasts of this island; as the former experiences more rain than the latter; nor on the summit, declivity, and base of most mountains, which differ in their degree of moisture.

It appears from hence, that the chemical analysis of soils is not yet arrived at sufficient accuracy to be depended upon with certainty to discover their degrees of fertility. But as the carbonic part of soil
probably

probably contributes most to the growth of vegetables, and next to that the calcareous part ; there is reason to conclude, that if a few pounds of different soils are dried by the same degree of heat, and then weighed, and afterwards exposed to a red heat in an open fire, that the soil, which loses most weight, is probably the most fertile ; because the carbonic matter will almost all escape in flame, and almost half the weight of the calcareous earth in carbonic acid.

Another method of giving some conjecture concerning the fertility of a soil may be by examining its specific gravity ; as the specific gravity of garden-mould is said by Muschenbroek to be 1,630, compared to 1,000 of water. And Fabroni found the specific gravity of barren sandy land to be 2,210 to 1,000 of water. This experiment would not be difficult to try with sufficient accuracy by drying two different soils at an equal distance from a fire, or in the same oven, and then weighing a pound of each in a thin bladder with apertures near its top or neck ; and then letting the bladder sink so low into water, as to admit the water through the apertures amongst the soil ; and lastly, observing the difference between their respective weights in air, and in water.

Nevertheless the method most in use by the purchasers of land to judge of its value is by attending to the growth and colour of the vegetables, which cover it ; which requires an experienced eye, and cannot be easily described in words. Add to this that vegetables, which grow wild on soils, will in some measure indicate the nature of them. As the digitalis, and arenaria, are found generally on sandy soils, the veronica becabunga, and cresses of some kinds, belong to moist situations, and others to mountainous ones. A particular catalogue of such plants, as spontaneously grow in different situations, might assist in discovering the degree of fertility, and the nature of the soil ; as other flowers by the time of their opening in each climate, which is termed the Calendar of Flora, may teach the temperature of the season.

In some parts of the country the spontaneous production of many
4 F docks,

docks, rumex, has been reckoned the mark of an inferior soil, and the production of thistles, *ferratula arvensis*, to be a sign of a good one; which explains a story in a black letter book on husbandry, which says, "A blind man went to purchase a farm, which was offered to sale, and riding over the pasture land, and hearing the goodness of the soil much applauded by the possessor, at length dismounted, and said to his servant, 'Tie my horse to a thistle!' 'Here are no thistles,' replies the servant, 'but I can tie him to a dock.' 'Then I will not purchase the land,' says he, and mounting his horse with a good morning to you, Sir, left the owner of the estate in great surprise."

10. *To be inserted at the end of Sect. XV. 3. 7.*

To discover when the seeds of herbaceous plants are ripe, as of wheat, the dryness or straw-colour of the stem is in general a good criterion; as when the stem dies, and becomes bleached by the oxygen of the atmosphere, no more nutriment can be conveyed to the mature seed. And to determine at what time to collect those fruits, which never ripen on the trees in this climate, as crab-apples, and baking-pears, change of colour or fall of the leaf shews, that they can acquire no more nourishment, and may receive injury from the approaching frost.

But to determine when our best or earliest apples and pears are ripe enough to gather, that is, when they will acquire no more nutriment from the tree, depends on a very curious circumstance of the colour of the skin of the seeds. During the infant state of the seed there is no cavity round them; but the seed is in contact with the seed-vessel, as may be seen on cutting an unripe pear or apple; and the seed therefore is perfectly etiolated, as it cannot part with any of its oxygen. Afterwards when there is no more deposition of nutritious

tious matter to enlarge the fruit, the cells, in which the seeds are contained, become hollow, producing an air-vessel for the living embryo; of what purity the air may be, which is produced in these cells, has not I believe been tried, and may differ as the embryo-feed grows older; but the oxygen, which it contains, seems to have been disengaged from the membranes, which cover the seeds, which thence become coloured; whence the dark colour of the seeds of apples and pears is a proper criterion of the time, when they should be gathered; as it indicates, that the fruit will no longer increase in size, as it now wastes and becomes hollow by absorbing some of the mucilage from the central parts of it.

11. *To be inserted at the end of Sect. VI. 5. 5.*

Sugar is not only afforded by the sap-flow of trees, as the maple, birch, and vine, but also I suppose from that of herbaceous vegetables, as heracleum spondilium, cow parsnip, and ferratula arvensis, field thistle; when the former of these plants has been cut off near the ground in the vernal months, the sap-juice from the stump I have observed to flow in such quantity for many days, that I have doubted whether by a proper apparatus for catching it the plant might not be advantageously cultivated for the purpose of making wine, or of extracting the sugar as from the maple of America. This circumstance has been said to shew a proper time for destroying the weeds, as if they be mowed in the bleeding season, they are believed to perish by the loss of sap-juice.

As all spirit is the same, when nicely distilled, whether it be found in wine, ale, cyder, brandy, rum, gin, and is the product of sugar by the chemical process of fermentation; and as all sugar is the same, when nicely cleaned, whether it be obtained from fruits, grains, roots, canes, or sap-juice; there is reason to believe, that sugar as well as

spirit may some time or other be economically procured from the vegetables of this climate, as Margraff extracted it from the beet-root, and from potatoes. For the strength of common ale, which is produced from the sugar contained in malt, is said to be about the same as that of some domestic wines, which owe their spirit to prepared sugar. And as in the former a bushel or strike of malt is used to about six gallons of water, and in the latter about twenty pounds of sugar to six gallons of water, it follows, that one strike of malt contains about twenty pounds of sugar; which if an easy method of cleaning it from the mucilage and from the essential oil of the feed could be discovered, it may some time be manufactured at home cheaper, than it can be procured from abroad.

We may add, as all sugar is the same, and all spirit is the same, from whatever plant they are procured; that the flavours of wines differ from each other solely in the essential oil, which they contain, or the quantity of acidity, or of sugar not yet fermented; and that in respect to wholesomeness wines only differ from each other in their strength or quantity of spirit, unless where some noxious material has been used to fine them, or to counteract their tendency to the acetous fermentation, as lead has been employed in some of the ciders of our country, and in some of the white wines of France, to correct their acidity; and it is said that arsenic is occasionally employed for the purpose of fining white wines.

The injurious methods of fining wines, and of stopping their tendency to acidity having been mentioned, the innocuous ones ought to be subjoined; for the former it has been proposed to filter muddy wine through fine sand laid on a sieve; but this I am told does not succeed, as the mucilage of the foul wine soon fills up the interstices of the grain of sands; but that an efficacious method is to shower the fine sand on the wine through a sieve; which as it passes down by its own weight will carry the mucilaginous mud of the wine along with it. And lastly, if some colouring particles cannot thus be
made

made to subside, a little more simple mucilage must be added, as gum arabic or whites of eggs, and a sand-shower be again passed through it.

In respect to the tendency of wines to become vinegar, this I am informed may be prevented by not exposing the fermenting material to the air more than can be easily prevented, as it is the union of the oxygen of the atmosphere with the spirit that converts it into vinegar; and though the vinous fermentation proceeds slower, when secluded from the air, yet it finally becomes more perfect; as the sugar in sweet wines continues to become spirit, after it is corked up in bottles, though the process is slower, and the wine consequently becomes stronger as it grows older, and the sweetness vanishes.

Hence I observe the manufacturers of raisin-wines set them to ferment in large casks with only the bung-hole open, that they may not be too much exposed to the atmosphere; and soon stop them up or bottle them, before the sweetness vanishes, which they judge of by the taste.

I was once told by a gentleman, who made a considerable quantity of cyder on his own estate, that he had procured vessels of stronger construction than usual, and that he directed the apple-juice, as soon as it had settled, to be bunged up close; and that though he had had one vessel or two occasionally burst by the expansion of the fermenting liquor, yet that this rarely occurred, and that his cyder never failed to be of the most excellent quality, and took a considerably greater price at market.

Nor should this account of fermentation be concluded without observing, that it converts sugar, which is a wholesome nutriment both to young and old, into spirit, which is a poisonous material to all; as it stimulates the whole system into too violent exertion for a few hours, and leaves it afterwards in consequence torpid and inactive; and hence that the strongest wines are the most pernicious, and that all of them should be diluted with water. As those in general, who
drink

drink ale to excess, acquire the gravel; those, who drink wine to excess, acquire the gout; and the drinkers of spirits die of the dropsy!—but it is the custom of most of the inebriates of this country to begin their unfortunate career with the first, and terminate it with the last.

12. *To be inserted at the end of Sect. X. 6. 8.*

An important paper concerning lime is this year published in the Philosophical Transactions by Mr. Tennant, who having been informed, that two kinds of lime were used in agriculture, which differed greatly in their effects, one of which it was necessary to use sparingly, and to spread very evenly over the land; for it was said, that a large proportion of it diminished the fertility of the soil; and that wherever a heap of it had been left on one spot, all vegetation was prevented for many years. And that of this kind of lime fifty or sixty bushels on an acre were as much as could be used with advantage; while of the other sort of lime a large quantity was never found to be injurious; and that the spots, which were entirely covered with it, became remarkably fertile, instead of being rendered barren.

Mr. Tennant having analysed those two kinds of lime found, that the latter consisted solely of calcareous earth; but that the former contained two parts of magnesia with three parts of calcareous earth. He afterwards observed, that though vegetable seeds would grow equally well in both these kinds of limestone, when simply reduced to powder; yet that, when they were calcined so as to become lime, and both of them strewed about the tenth of an inch thick on garden mould, that the magnesian lime prevented nearly all the seeds, which had been sowed, from coming up; while no injury was occasioned by the calcareous lime used in the same manner.

This important discovery seems to explain the cause of such variety of opinion about the use of lime, which some have believed to be of

no advantage, and even injurious to land; which has probably been owing to their having used the magnesian lime, and having laid on too much of it.

Mr. Tennant first found magnesian lime near the town of Doncaster, and afterwards at York, at Matlock in Derbyshire, and at Breedon in Leicestershire, and at Workfop in Nottinghamshire. He observes, that the cathedral and walls of York are built with this magnesian limestone; and that at Matlock the magnesian and calcareous limestones are contiguous to each other; the rocks on the side of the river Derwent, where the houses are built, being magnesian; and on the other side calcareous. He observed also here, that the magnesian limestone was incumbent on the calcareous; for in descending into a cave formed in that rock, he found a separate vein of calcareous limestone, which was full of shells, but contained no magnesia; and observes in general, that magnesian limestone may be readily distinguished from the calcareous by its so much slower solution in acids, and that it contains generally very few shells, but that those also are impregnated with magnesia.

As all limestone may be divided into three kinds; the rocks, which remain, where they were formed from shells beneath the ocean, except that they were afterwards elevated by submarine fires; and secondly into alluvial limestone, as those which have been dissolved in water, and simply precipitated, as the beds of chalk, which contain only the most insoluble remains of sea-animals, as the teeth of sharks; and thirdly those which after having been dissolved and precipitated, have been long agitated beneath the sea, till the particles have been rolled so against each other, as to acquire a globular form, which is said to resemble the roe, or spawn, of fish, and which contain very few shells or none, as the Ketton stone, and that which I have seen on Lincoln Heath extending almost from Sleaford to Lincoln.

Now as the salts of the sea consist of only two kinds, common salt,

salt, or muriate of soda, and vitriolated magnesia, commonly called Epsom salt, which in the sea-waters surrounding this island were found at a medium to exist in the proportion of one thirtieth part of common salt, and one eightieth part of vitriolated magnesia compared to the quantity of water. And secondly as these salts are believed by many philosophers to have been formed by vegetable and animal matters, which principally grew upon the surface of the dry land, after it was raised out of the primeval ocean; and that in consequence the saltiness of the sea was posterior to the formation of the primeval rocks of limestone; and from hence we understand, why those limestone strata, which have not been dissolved or washed in sea-water since the sea became salt, are not mixed with magnesia.

The chalk must have been dissolved and precipitated from water, as it exactly resembles the internal part of some calcareous stalactites, which I have in my possession; yet there is no appearance of its component particles having been rubbed together into small globules, and may not therefore have been removed from the situation, where it was produced, except by its elevation above the surface of the ocean.

But that alluvial limestone, which consists of small globules adhering together, called Ketton limestone, and of which there appears to be a bed ten miles broad from Beckingham to Sleaford in Lincolnshire, and twenty miles long from Sleaford to Lincoln, I suspect may probably consist of magnesian limestone; which is also said in that country to do no service to vegetation; for this alluvial limestone by having evidently been long rolled together beneath the sea, by which the small crystallised parts of it have had their angles rubbed off, is most likely to have thus been mixed with the magnesia of the sea-water, which is said to contain one eightieth part of its weight of vitriolated magnesia, as above mentioned.

At the lime-works at Ticknal near Derby there appears a stratum
of

of alluvial limestone, like Ketton limestone, which they do not burn for sale, over the bed of the calcareous limestone, which they get from beneath the former, and calcine for sale. It is probable, that the superior bed may contain magnesia, which has rendered it not so useful in agriculture.

It is more probable, that alluvial limestone has acquired its mixture of magnesia from the sea-water; as magnesia in its uncalcined state will precipitate lime from water, as observed by Dr. Alston; who thence proposes to render water pure and potable, which has been long kept at sea free from putridity by having lime mixed with it, by precipitating the lime by the addition of mild magnesia; which is a subject now perhaps worthy the attention of the court of admiralty, since magnesian limestone appears to be so plentifully diffused over the earth. See Dr. Black's Exper. on Magnesia in the Essay Philos. and Literary, Edinb.

The lime from Breedon is magnesian, that from Ticknal (which is sold) is calcareous lime I believe; and some farmers in the vicinity of Derby assert, that two loads of Breedon lime will *go as far*, that is will apparently do as much service to their land as three loads of Ticknal lime. Breedon lime, I am also informed, is preferred in architecture, and is said to *go further* in making mortar; which I suppose means, that it requires more sand to be mixed with it. Mr. Marshall in his account of the agriculture of the Midland counties speaks of lime made at Breedon near Derby as destructive to vegetables when used in large quantities. And in Nottinghamshire it is asserted, that the lime from Critch in Derbyshire is so mild, that thistles and grass spring up through the edges of large heaps of it, when laid in the fields. Dr. Fenwick of Newcastle observes, that the farmers in that country divide lime into hot and mild; which Mr. Tennant believes to mean magnesian and calcareous lime.

By experiments which were made by Mr. Tennant by sowing seeds of colewort on various mixtures of calcined magnesia with soil, and

of calcareous lime with soil, he found that thirty or forty grains of lime did not retard the growth of seeds more than three or four of calcined magnesia; from hence what can we conclude? but that, as they both injure vegetation in large quantities, they may both assist vegetation in small ones? and that this is more probable, as the farmers believe, that they find both of them useful, though in different quantities; and as the magnesia would form Epsom salt, if it meets with vitriolic acid, which Dr. Home found from his experiments to be friendly to vegetation, when used in very small quantities. More accurate observations and more numerous experiments on this subject are required, which this important discovery of Mr. Tennant's will I hope soon occasion.

13. *To be inserted at p. 286, l. 16, at the end of No. 2 of Sect. XII.*

Another method has been attempted by some for the purpose of ameliorating clayey lands, which were unfit to be turned up deeper than they had been accustomed to be ploughed, on account of their acidity or tenacity being very injurious to vegetation; as the white saggar clays over many coal countries; or some very tenacious red clays, which may contain a vitriol of iron; not an oxyde, or oxygenated calx of it.

The method I allude to consists in first turning over a ridge of earth, as in common-ploughing; and then with a plough, made on purpose, to penetrate some inches deeper into the clay so injurious to vegetation; this plough is to be so contrived, as to raise up the clayey soil about the breadth of the furrow recently made, and three or four inches deep, or more; but not to turn it over, so that it may still lie under the fertile soil, which is to be turned over it with the common plough, in making the adjoining furrow. So that this
plough

plough is only to pass under the foil, and thus loosen it, and mix it with atmospheric air without turning it over.

By this manœuvre the clay a few inches deep beneath the fertile foil becomes broken in its texture, and obtains some air intercepted in its pores; from the former circumstance it may contribute to retain the vernal showers, which would otherwise run off over the clayey surface beneath the more fertile one, and might thus in drier seasons prevent the upper surface from being so much indurated, and might gradually become less injurious by the frequent admixture of atmospheric air, and at length even salubrious to the roots of vegetables.

A P P E N D I X.

IMPROVEMENT OF THE DRILL PLOUGH.

THE first experiment I tried to improve this valuable machine was that mentioned in Sect. XII. 5. of this work, by enlarging the axis of Mr. Tull's seed-box into a wheel of sixteen inches diameter, with excavations in the rim to raise portions of the corn above the surface of that in the seed-box. But I found to my surprise the friction of the corn to be so much greater than expected, when six such large wheels were immersed in it, that an additional hopper became necessary to deliver the seed slowly into the seed-box, as in Mr. Cook's drill plough; which, as it would add much to the intricacy and expence of the machinery, and to the inaccuracy of the quantity of seed delivered, occasioned me to relinquish that idea, and after many designs and many experiments to construct the following machine, which I believe to be more simple, and consequently less expensive to construct, and less liable to be out of order, and to deliver the seeds of all kinds with greater accuracy than any drill plough at present in use; and that it possesses every other advantage that they can boast. The scale of the three following plates is half an inch to ten inches.

Construction of the Carriage Part.

Plate X. Fig. 1. *a a*, are the shafts for the horse, which are fixed to the center of the axle-tree by a simple universal joint at *z*, whence,

if the horse swerve from a straight line, or is purposely made to pass obliquely to avoid treading on the rows of corn in hoeing; the person, who guides the plough behind, may keep the coulters of the plough or hoe in any line he pleases; which is thus performed with much simpler mechanism, than that used in Mr. Cook's patent plough for the same purpose, which has many joints like a parallel rule.

bb are the horns or shafts behind, for the person who guides the drill coulters or hoes; they are fixed to the axle-tree before, and have a cross piece about six inches from it at *gg* for the purpose of supporting the seed-box described below. Behind this about a foot distant from it is another cross piece at *cc*, called the coulters-beam, which is fifty inches long, six inches wide, and two inches thick; it is perforated with two sets of square holes, six in each set, to receive the coulters in drill-ploughing, and the hoes in horse-hoeing.

The six light square holes are nine inches from each other, and are to receive the coulters or hoes in the cultivation of wheat, the rows of which are designed to be nine inches from each other, and the six dark square holes are placed seven inches from each other to receive the coulters or hoes for the cultivation of barley, the rows of which are designed to be but seven inches distant from each other.

Besides these there are six round holes through this coulters-beam at one part of it, and six iron circular staples fixed into the edge of the other part of it; these are to receive the ends of the tin flues, which cross each other, and convey the seed from the bottom of the seed-box into the drills or furrows, when the coulters are disposed in the square perforations before them.

These coulters or hoes the person, who guides the machine, can raise out of the ground in turning at the ends of the lands, or in passing to or from the field, and can suspend them so raised on the iron springs *dd*, which at the same time so fixes the shafts to the axle-tree

tree that the wheels will then follow in the same line with the horse.

ee are wheels of four feet in diameter, the nave of one of which has on it a cast-iron wheel at *ff*, for the purpose of turning the axis of the feed-box, which has a similar wheel of one fourth its diameter; whence the axis of the feed-box revolves four times to one revolution of the wheel.

Construction of the feed-box. Plate XI. Fig. 2.

This consists of boards about an inch in thickness, is forty-eight inches long within, twelve inches deep, twelve inches wide at top, and six inches wide at bottom; it is divided into six cells, in which the corn is to be put, as represented in Plate XI. Fig. 2. and should also have a cover with hinges to keep out the rain, and is to be placed in part over, and in part before, the axle-tree of the carriage, at *gg*. Plate X. Fig. 1.

Beneath the bottom of the feed-box passes a wooden cylinder, at *bb*, Plate XI. Fig. 2. with excavations in its periphery to receive the grain from the six cells of the feed-box, *lmnopq*, and to deliver it into the six oblique flues *ii*, which are made of tin, and cross each other, as represented in the plate. The use of the feed-flues thus intersecting each other is to increase the length of the inclined surface, on which the seed descends, that if six or eight grains be delivered together, they might so separate by their friction in descending, as not to be sown together in one point, which might be liable to produce tufts of corn.

As these feed-flues cross each other, before they pass through the coulter-beam at *cc*, Plate X. Fig. 1. it was necessary to make three of the round holes of the coulter-beam at one end backward than those at the other end; and on that account to use iron staples or

rings at one end instead of perforations, as at *ww*, Plate X. Fig. 1. These tin flues deliver the seed at the time of sowing into the small furrows or drills, which are made by the coulter before them.

These feed-flues have a joint at *zz*, where one part of the tin tubes slides into the other part, and they by these means can be occasionally shortened or lengthened to accommodate them to the coulters, when placed at seven inches distance for sowing barley, or at nine for sowing wheat.

At the bottom of this seed-box are six holes, one in each cell, to deliver the corn into the excavations of the cylinder, which revolves beneath them. These holes are furnished on the descending side, as the cylinder revolves, with a strong brush of bristles about three fourths of an inch long, which press hard on the tin cylinder. On the ascending side of the revolving cylinder the holes at the bottom of the seed-box are furnished with a piece of strong shoe-soal leather, which rubs upon the ascending side of the cylinder. By these means the corn, whether beans or wheat, is nicely delivered, as the axis revolves, without any of them being cut or bruised.

Construction of the iron axis and wooden cylinder beneath the seed-box.

Plate XI. Fig. 3.

An iron bar is first made about four feet six-inches in length, and an inch square, which ought to weigh about fifteen pounds; this bar is covered with wood, so as to make a cylinder four feet long, and two inches in diameter, as at *kk*, Plate XI. Fig. 3. The use of the iron bar in the centre of the wood is to prevent it from warping, which is a matter of great consequence.

This wooden cylinder passes beneath the bottom of the seed-box, and has a cast-iron cog-wheel at one end of its axis, as at *rr*, which is one fourth of the diameter of the correspondent cast-iron wheel,
which

which is fixed on the nave of the carriage-wheel, as in Plate X. Fig. 1. *ff*, so that the axis of the feed-box revolves four times during every revolution of the wheels of the carriage.

In the periphery of this wooden cylinder are excavated four lines of holes, six in each line, as at *nnnnnn*. A second line of excavations is made opposite to these on the other side of the cylinder, and two other lines of excavations between these; so that there are in all twenty-four excavations in the wooden part of this axis beneath the feed-box, which excavations receive the corn from the feed-cells, as the axis revolves, and deliver it into the flues shewn in Plate XI. Fig. 2. *ooii*, not unfimilar to the original design of the ingenious Mr. Tull.

The size of these excavations in the wooden cylinder to receive the feed are an inch long, half an inch wide, and three eighths of an inch deep; which are too large for any feeds at present employed in large quantities except beans, but have a method to contract them to any dimensions required, by moving the tin cylinder over the wooden one, as explained below in Plate XI. Fig. 4.

Construction of the Tin-cylinder. Plate XI.

A B at Fig. 4. represents a cylinder of tin an inch longer within than the wooden cylinder on the iron axis at Fig. 3. and is of two inches diameter within, so as exactly to receive the wooden cylinder, which may slide about an inch backwards or forwards within it. C D are two square tin sockets fixed on the ends of the tin cylinder to fit on the square part of the iron axis, which passes through the wooden cylinder at *ll*, Fig. 3. on which they slide one inch backwards or forwards.

The following directions in making the holes in this tin cylinder,

4 H

and

and those in the wooden cylinder, which are to correspond with them, must be nicely attended to.

First, when the tin-cylinder is foldered longitudinally, and one end of it foldered on, as at A, six holes through it must be made longitudinally on four opposite sides of it, each hole must be exactly half an inch wide, and five eighths of an inch long, the length to be parallel to the length of the cylinder.

The centre of the first of these holes must be five inches distant from the closed end A, the centre of the second hole must be eight inches distant from the centre of the first, and so on till six holes are made longitudinally along the cylinder. Then another such line of six similar-holes is to be made on the opposite side of the cylinder, and then two other such lines between the former, in all twenty-four; and the size of all these holes must be nicely observed, as well as their distances.

Secondly. The wooden cylinder fixed on the axis is now to be introduced into the tin cylinder, but not quite to the end of it, but so as to leave exactly one inch of void space at the closed end A, and then the size of all these apertures through the tin cylinder, each of which is exactly half an inch wide, and five eighths of an inch long, are to be nicely marked with a fine point on the wooden cylinder, which must not previously have any excavations made in it.

Thirdly. The twenty-four holes thus marked on the wooden cylinder are now to be excavated exactly three eighths of an inch deep, but with an addition also of three eighths of an inch at that end of every one of them which is next to A; so that, when the wooden cylinder is again replaced in the tin cylinder as before, with one inch of void space at the closed extremity of it, the excavations in the wooden cylinder will be three eighths of an inch longer, than the perforations in the tin cylinder over them. These excavations in the wooden cylinder must also be rather narrower at the bottom than at the

the top, to prevent with certainty any of the grain from sticking in them, as they revolve.

Fourthly. A screw of iron about three inches long, with a square head to receive a screw-driver, is to pass through the end A of the tin cylinder on one side of the axis, as at *x*, Fig. 4. The screw part of this is to lie in a hollow groove of the wooden cylinder, and to be received into a nut, or female screw, which is fixed to the wooden cylinder. The head part of the screw, which passes through the end A of the tin cylinder at *x*, must have a shoulder within the tin cylinder, that it may not come forwards through the end of it; and a brass ring must be put over the square end of the screw on the outside of the tin cylinder, with a pin through that square end of the screw to hold on the brass ring.

Thus when the square head of the screw is turned by a screw-driver, it gradually moves the tin cylinder backwards and forwards one inch on the wooden one, so as either to press the end A of the tin cylinder into contact with the end of the wooden cylinder within it, or to remove it to the distance of one inch from it, and leave a void space at the end A.

Fifthly. The ends of all the holes of the tin cylinder, which are next to the end A of it, are now to be enlarged, by flitting the tin three eighths of an inch towards A, on each side of the hole; and then that part of the tin, included between these two flits, which will be half an inch wide, and three eighths of an inch lengthways in respect to the cylinder, is not to be cut out, but to be bent down into the excavations of the wooden cylinder beneath, so as to lie against that end of the excavation which is next to A.

But these projecting bits of tin, before they are bent down into the excavations of the wooden cylinder, must be filed a little less at the projecting end, which is to be bent down, than at the other end; as the excavations of the wooden cylinder are to be rather narrower

at the bottom than at the top, and these pieces of tin, when bent down, must exactly fit them.

Lastly. When all these holes through the tin-cylinder are thus enlarged, and the bits of tin filed rather narrower at their projecting ends, and then bent down into the excavations of the wooden cylinder, the other end of the tin cylinder with its square socket may be foldered on.

And now when the end of the tin cylinder at A is pressed forwards upon the wooden cylinder towards B, by turning the screw at *x* above described; every excavation of the wooden cylinder will be gradually lessened, and finally quite closed; by which easy means they may be adapted to receive and deliver seeds of any size from horse-beans and peas to wheat, barley, and to turnip-feed, with the greatest accuracy, so as to sow four, five, or six pecks on an acre, or more or less, as the agricultor pleases, by only turning the screw a few revolutions one way or the other.

Observations.

1. In the construction of the tin and wooden cylinders beneath the feed-box another small improvement may be necessary in sowing very small seeds, which is this: As the screw at the end A is turned, so as to contract all the excavations of the wooden cylinder, the surface of the wooden cylinder for one inch from the end of each excavation towards the end B, Plate XI. Fig. 4. will become bare without being covered by the tin cylinder; and on these bare parts of the wooden cylinder, which will be one inch long, and half an inch wide, some small seeds may chance to stick, and evade the brushes, which should prevent them from passing, as the cylinders revolve.

To prevent this, when the wooden cylinder is so placed within the tin cylinder, that all the holes are quite open, let a piece of the tin cylinder

cylinder about an inch and a half long, and half an inch wide, be cut out from the extremity of each hole next to the end B, and let this piece of the tin cylinder thus cut out be fixed by a few sprigs on the wooden cylinder exactly in the same place, which it covered before it was cut out of the tin one, by which contrivance, when the tin cylinder is afterwards pushed forwards by turning the screw at its end, so as to contract the excavations of the wooden cylinder beneath, the bare parts of the wooden cylinder will exist an inch and a half from the extremities of the excavations next to the end B, and thus will not pass under the brushes, and in consequence no small seeds can lodge in them.

2. Some kind of iron staple should be fixed at each end of the feed-box on the outside, which when the hinder part of the carriage is raised up by the person who guides it, might catch hold of the two iron springs at *dd* in Plate X. Fig. 1. for the purpose of suspending the coulters out of the ground, and connecting the hinder part of the machine with the shafts before; that in turning at the ends of the lands, or in passing from or to the field, the wheels may not swerve at the joint *z*, at the centre of the axle-tree, but may follow in the same line with the shafts.

3. The feed-box must also be supported on upright iron pins passing through iron staples, with a lever under the end of it next to the wheel *rr*, Plate XI. Fig. 3. for the purpose of easily lifting that end of the feed-box about an inch high, to raise the teeth of the iron cog-wheel on its axis out of the teeth of the correspondent iron wheel on the nave of the carriage-wheel.

4. The construction of the coulters, which make the drills, and of the rakes, which again fill them, after the feed is deposited, and also of the hoes, are not here delineated; as they are similar to those so often described or used by Mr. Tull and his followers.

5. When the lower ends of the feed-flues are placed through the holes in the coulters-beam, Plate I. Fig. 1. at nine inches distance from

from each other, the rows of wheat or beans will then be sown nine inches from each other; and as the wheels of the carriage are four feet in diameter, and therefore travel about twelve feet at each revolution; and as there are four excavations round the axis of the feed-box, which revolve four times for one revolution of the carriage-wheels; it follows, that the seeds contained in the excavations of the cylinder beneath the feed-box will be sown at nine inches distance in each drill or furrow, as the plough proceeds; and as these rows are nine inches asunder, any desired number of seeds may be deposited in every square of nine inches, which are contained in the surface of the field.

6. Mr. Coke of Norfolk acquainted me, that on his very extensive farm the wheat sown on an acre was six or seven pecks by the Rev. Mr. Cook's drill plough, which was about half the quantity generally used in broad-cast sowing. If the wheat was nicely deposited in the drills, I suspect one bushel would be quite sufficient for an acre, as the rows are at nine inches distant from each other; for there would in that case be about eight grains or nine grains deposited in every nine inches of the drill-furrow; that is, in every square of nine inches contained in the surface of the land so cultivated.

Which may be thus estimated. Mr. Charles Miller, in the *Philosophical Transactions*, Vol. LVIII. p. 203, has estimated the number of grains in a bushel of wheat to amount to 620,000; and Mr. Swanwick of Derby has lately estimated them to be 645,000. We may suppose therefore, that a bushel may at an average contain 635,000 grains of wheat. Now as a statute acre contains 4840 square yards, and there are sixteen squares of nine inches in every square yard, 4840 multiplied by 16 gives 77,440, which is the number of squares of nine inches in such an acre. If 635,000 grains in a bushel be divided by 77,440, the number of squares of nine inches in an acre, the quotient will shew, that rather more than
eight

eight grains of wheat will thus be deposited in every nine inches of the drills.

7. Now if eight or nine grains were dropped altogether in one inch of ground, they would be too numerous, if they be all supposed to grow, and would form a tussock; but by making them slide down an inclined plane, as in the tin-flues, from the seed-box to the coulters, which are crossed for the purpose of lengthening them, as seen in Plate XI. fig. 2. some of the seeds will be more delayed by their friction in descending than others, and the eight or nine seeds will thence be dispersed over the whole nine inches of the drill; which renders drill-sowing superior to dibbling, as in the latter the seeds are dropped all together.

8. When the holes in the wooden cylinder are completely open, they are about a proper size for sowing horse-beans or peas: when they are completely closed, there will remain a small niche at the end of the excavation in the wooden cylinder next to B, Plate XI. fig. 4. for turnip-feed, or other small seeds.

For wheat and barley and oats, a wooden wedge should be made of the exact shape of the area of the hole, which the director of the plough requires; who will occasionally insert it into the holes, when he turns the screw at the end of the cylinder to enlarge or to lessen them to these exact dimensions.

These wedges should be written upon with white paint, wheat, barley, oats, &c. which will much facilitate the adapting the size of the excavations to each kind of grain, and may be altered, if required, to suit larger or less seeds of the same denomination.

9. In some drill-ploughs, as in Mr. Cook's, there is an additional machinery to mark a line, as the plough proceeds, in which the wheel nearest the last sown furrow may be directed to pass at a proper distance from it, and parallel to it. But in sowing wheat or peas and beans this may be done by making the wheels, as they run upon the ground, to be exactly fifty-four inches from each other; and

then at the time of sowing to guide the wheel next to the part last sown exactly in the rut, which was last made; by which guide the rows will all of them be accurately at nine inches distant from each other.

The Simplicity of this Drill-Plough.

1. The simplicity of this machine consists first in its having only a feed-box, and not both a hopper and a feed-box, as in the Rev. Mr. Cook's patent drill-plough.

2. The flues, which conduct the seed from the bottom of the feed-box into the drill-furrows, are not disjoined about the middle of them to permit the lower part to move to the right or left, when the horse swerves from the line, in which the coulter passes, as in Mr. Cook's patent drill-plough; which is done in this machine by the simple universal joint at *z*, Plate I. fig. 1.

3. In this machine the horns or shafts behind, between which the person walks, who guides the coulters, are fixed both to the coulters-beam, and to the axle-tree; whereas in Mr. Cook's patent plough these are all of them moveable joints like a parallel rule, for the purpose of counteracting the swerving of the horse; which in this machine is done by the simple universal joint at *z*, fig. 1, Plate I. before mentioned.

4. The altering the dimensions of the holes in the axis of the feed-box by only turning a screw, so as to adapt them to all kinds of seeds, which are usually sown on field-lands.

5. The strong brush of bristles, which sweep over the excavations of the cylinders beneath the feed-box, strickle them with such exactness, that no supernumerary seeds escape, and yet none of them are

in the least bruised or broken, as I believe is liable to occur in Mr. Tull's original machine.

Lastly it should be observed, that the less expence in the construction, the less propensity to be out of repair, and the greater ease of understanding the management of this machine, correspond with its greater simplicity; and will, I hope, facilitate the use of the drill-husbandry.

Mr. Swanwick's Seed-Box.

As the dibbling of wheat, described in Sect. XVI. 2. 2. is a very slow and laborious method of depositing the corn, and is yet coming, as I am informed, more and more into fashion in some counties, I suspect this must be owing to the expence of procuring, and the difficulty of managing the drill-ploughs now in use, or to the greater inaccuracy, with which they deliver the seed. I flatter myself therefore, that I am doing a benefit to society in endeavouring to simplify this machine, and to increase its accuracy as much as possible: and shall therefore here describe another method of delivering the seed from the seed-box, which was invented by Mr. Swanwick, an ingenious teacher of writing and arithmetic, with some branches of natural philosophy, in Derby; and who will not be averse to shew the working models of the seed-boxes, or to give assistance to any one, who wishes to construct either this drill machine, or the preceding one.

Mr. Swanwick's seed-box is forty-eight inches long within, is divided into six cells for the purpose of sowing six rows of seeds at the same time, like that above described. And at the bottom of each cell is a hole *a, a*, &c. Fig. 1. Plate XII. for the seed to pass

through into the feed-flues, as in the machine before described: but in this there is no revolving axis, but a wooden or iron bar *BB*, fig. 3. Plate XII. about two inches broad, and about four feet eight inches long, and exactly three eighths of an inch thick. Through this bar there are six perforations, *eee*, &c. which are each of them exactly one inch long, and half an inch wide; and three eighths of an inch deep, which is the thickness of the bar. The centres of these holes are exactly eight inches distant from each other, correspondent to the holes at the bottom of the feed-box; over which it is made to slide backward and forwards in a groove. By this sliding motion it passes under stiff brushes, which are placed over it on each end of the holes at the bottom of the feed-box, and strickle off the grain, as the holes in the sliding-bar pass under them, which thus measure out the quantity with considerable accuracy.

In order to increase or diminish the quantity of grain delivered, the slider is covered with a case of tin *CC*, fig. 4, Plate XII. which has six perforations exactly corresponding with the holes in the slider; but instead of the bit of tin being cut out the whole length of the hole, part of it is left at the end *i*, fig. 6, equal to the thickness of the slider, and is bent down as at *h*, after the slider is put into the case, like the tin cylinder in the preceding machine. This case is moveable about one inch backward and forward by turning the finger-screw *s*, fig. 4 and 5; and thus the holes are made larger or less to suit various sorts of grain, or different quantities of the same sort; exactly as in the wooden and tin cylinders in Plate XI. The slider is moved forwards by a bent iron pin *b* attached to it, which passes into a serpentine groove *Y*, fig. 5, fixed to the nave of the wheel: and backwards by a steel spring at the other end of the feed-box, which is not represented in the plate.

Fig. 5 is a bird's eye view of the parts before described: *EE* the feed-box divided into cells by the partitions *dd*, &c.—*ccc* the slider,

with a part of the apertures seen just appearing from under the brushes. X the axis of the wheel.

Fig. 6 is a drawing of part of the tin case, nearly of the full dimensions as to breadth and thickness, but only a small portion of the length; and is intended to shew more distinctly the construction of it.

Fig. 2 represents a side-view of one of the six bridges lying over the holes at the bottom of the feed-box, on each side of which the brushes are fixed, which strickle the holes, when they are full of corn, as the bar slides backwards and forwards.

The simplicity of this slider at the bottom of the feed-box may be in some respects greater, than that of wooden and tin cylinders in the former machine; as this has but six holes to measure out the corn, and the other has twenty-four. But perhaps in other respects less so; as in this twelve brushes are used, one on each side of each of the six holes; whereas there are only six brushes rub upon the tin cylinder in the former machine. And the reciprocating motion of this slider must be quick, as it must act once every time the periphery of the wheel of the carriage has passed nine inches forward; which may not be so easy to execute as the cog-wheel, and uninterrupted movement of the axis and cylinder in the preceding machine.

I have only to add, that the facility of adapting the holes to the dimensions required in both these machines, and their not bruising or breaking the grain in their operation of delivering it, as well as their not being encumbered with an additional hopper, which must deliver the quantity of seed with great inaccuracy from the unequal shaking of the machine, adds much to the excellency and simplicity of them both. And I hope will render more general the use of the drill husbandry invented by the ingenious Mr. TULL; who was on

that account an honour to this country, and ought to have a statue erected to his memory, as a benefactor of mankind, like Ceres and Triptolémus of old.

Ille Ego, qui quondam gracili modulatus avena
 Carmen, et egressus sylvis vicina coegi,
 Ut quamvis avido parerent arva colono.

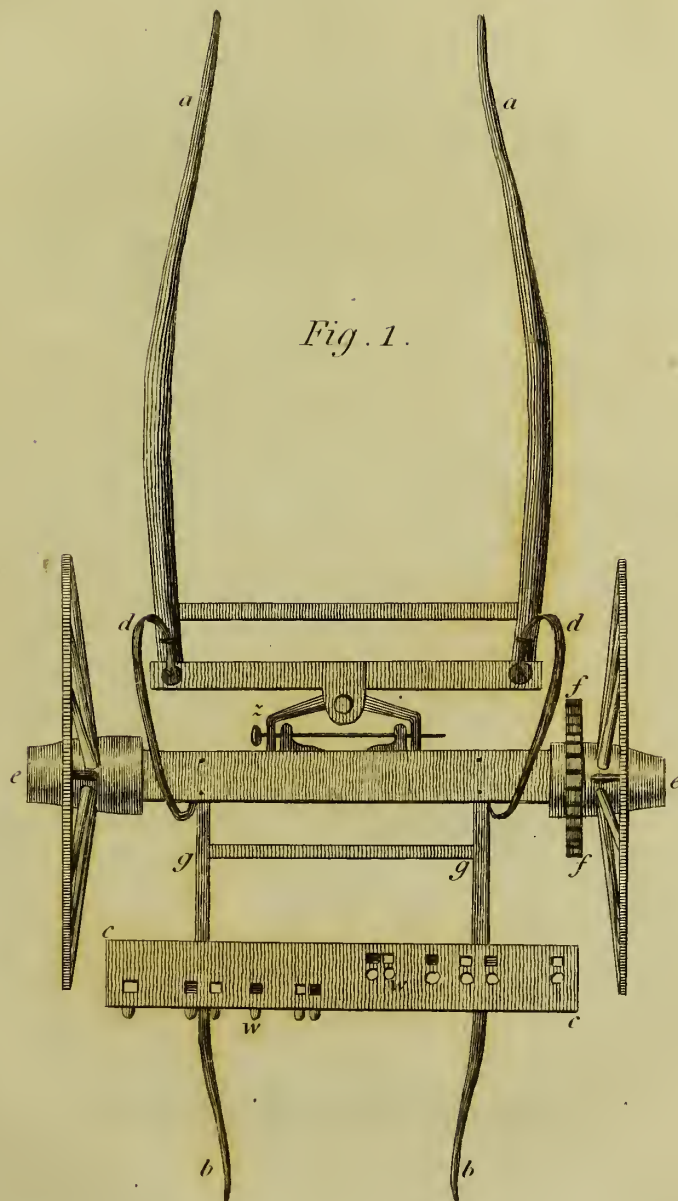


Fig. 2.

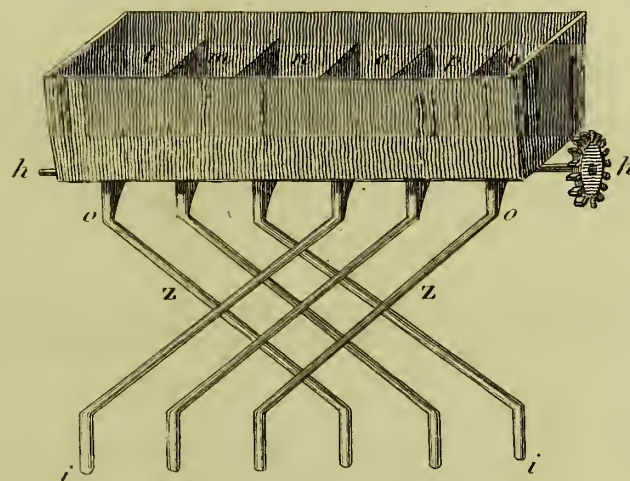


Fig. 3.

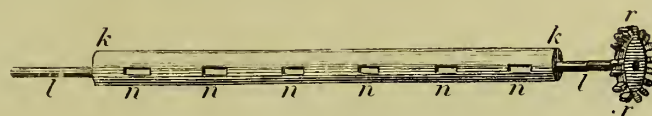
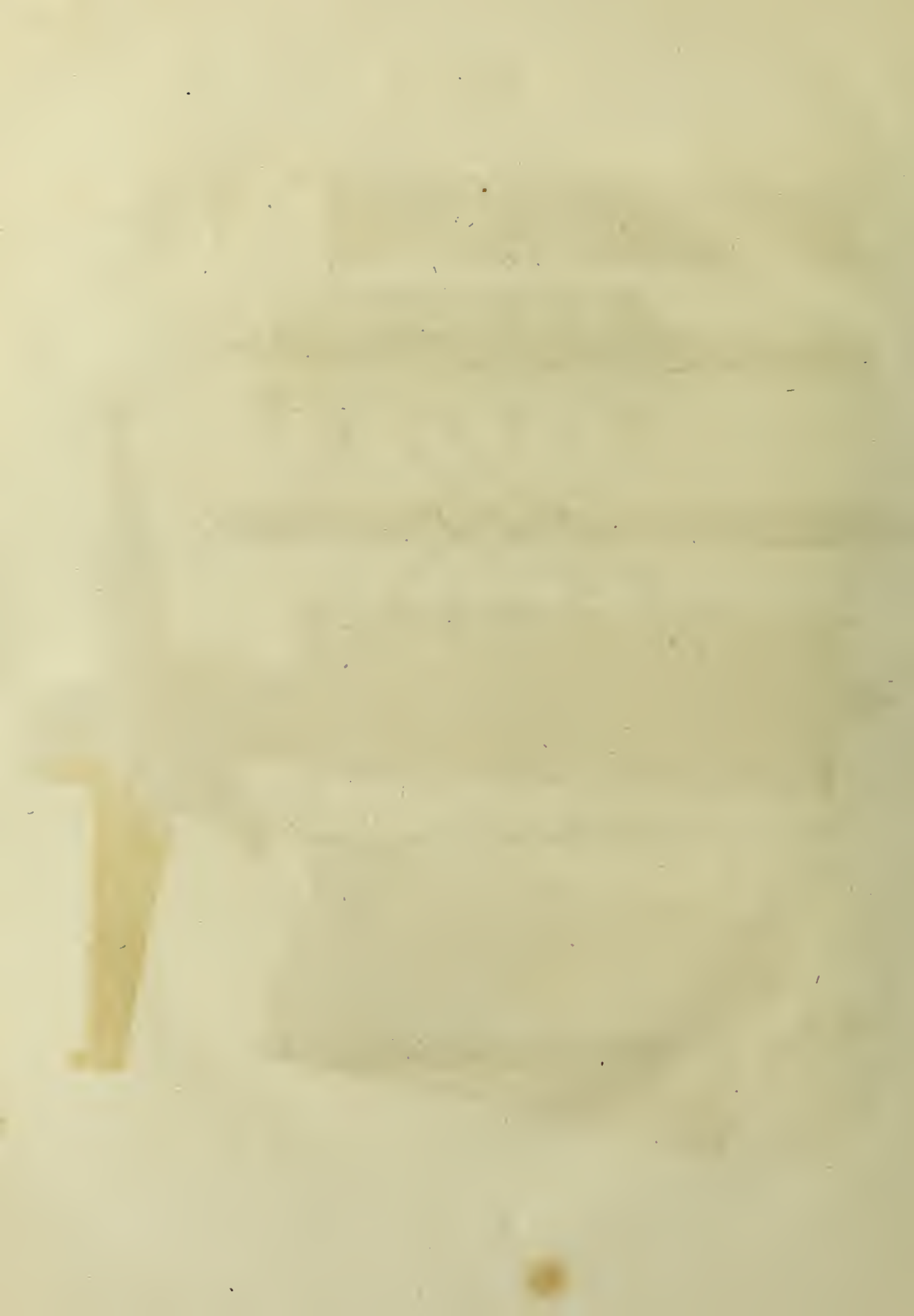
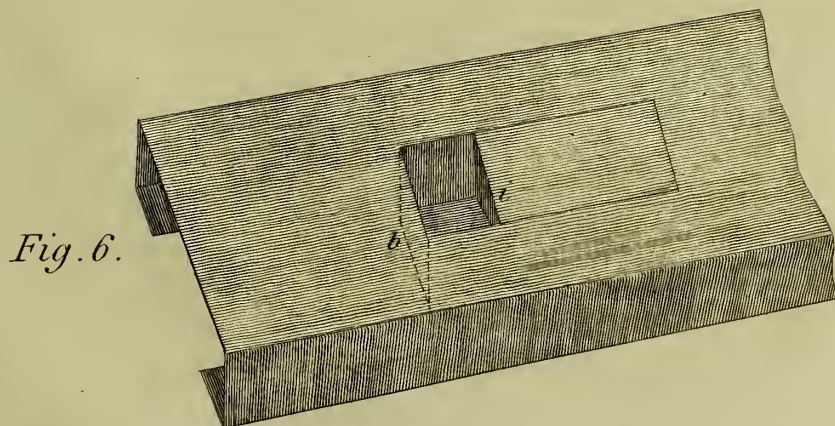
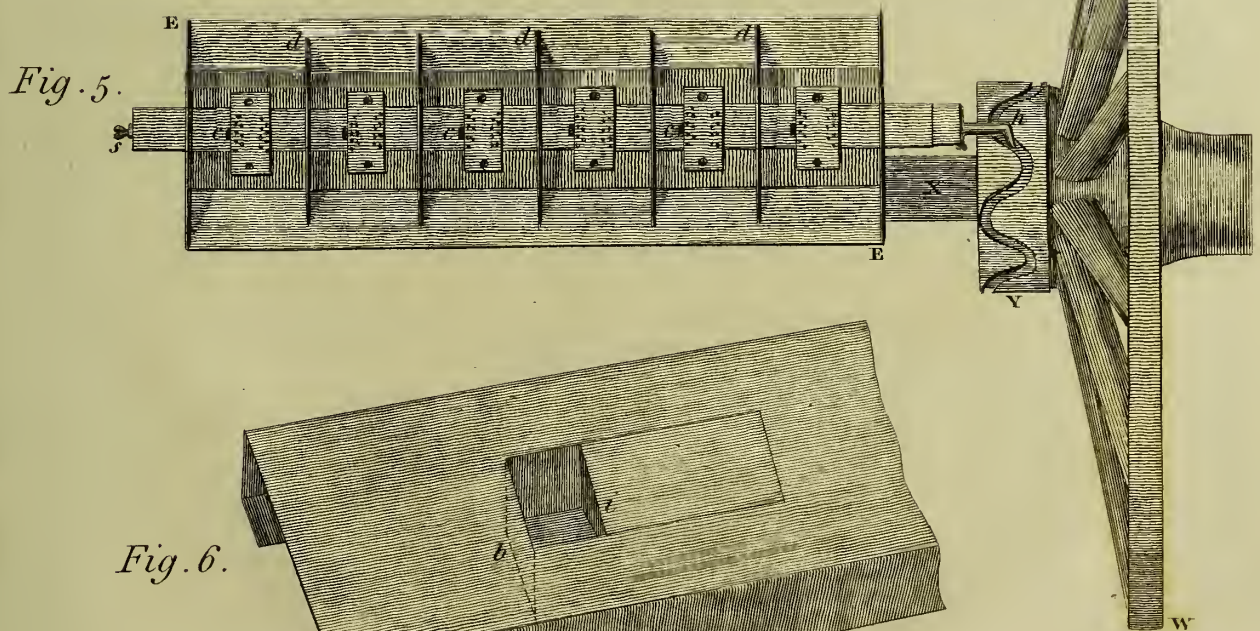
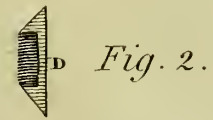
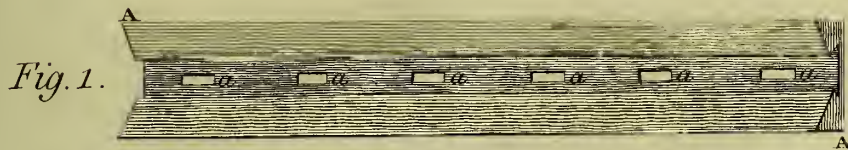
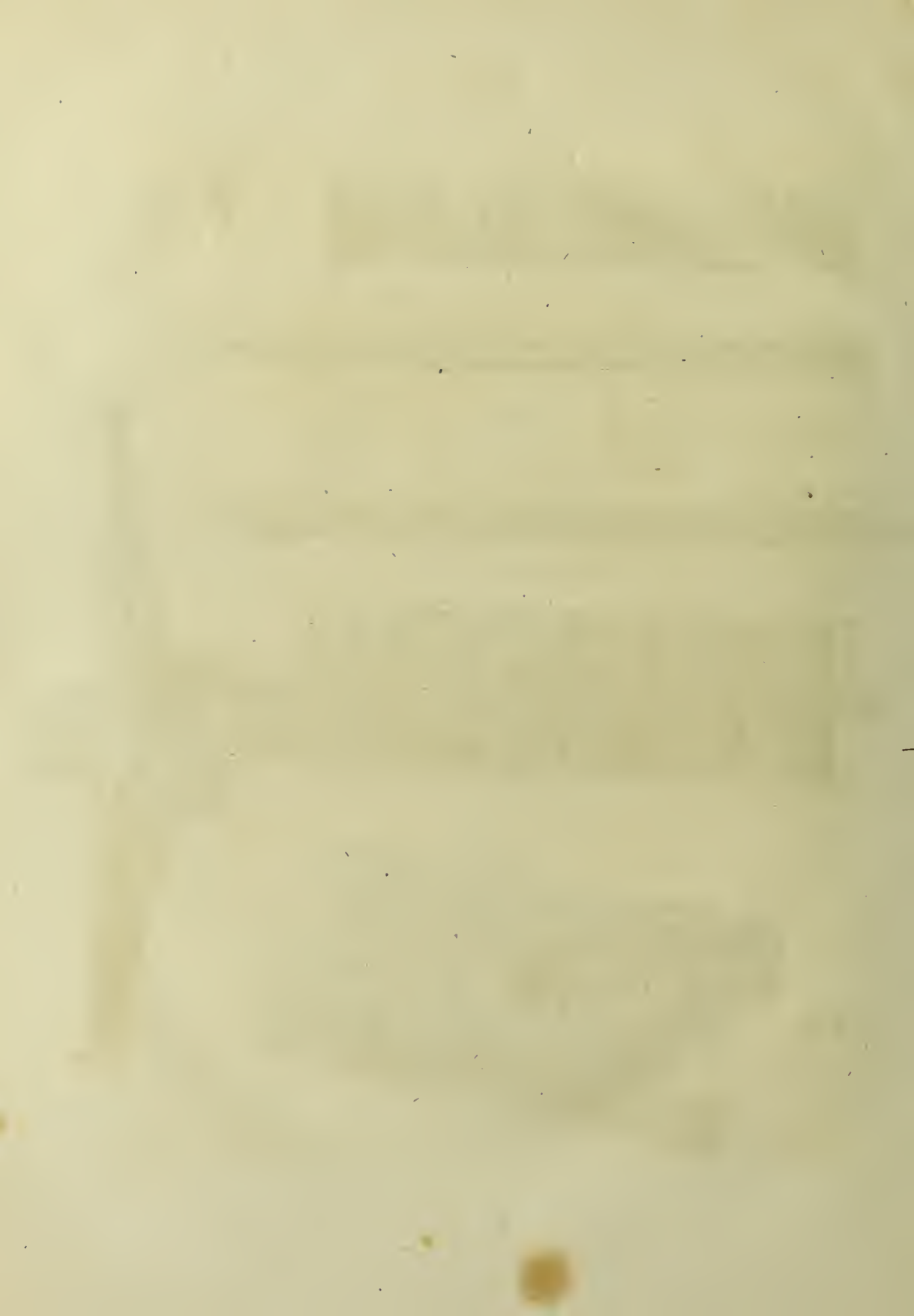


Fig. 4.









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- Plate III. at the end of Sect. III. between p. 38 and 39.
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